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Redesigning Reverse Engineering Curriculum

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Redesigning Reverse Engineering Curriculum

by

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Report

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Dedication

This report is dedicated to my dad, Lane Howard, who put up with me as a curious kid hanging over the side of his 1972 Chevrolet El Camino. He let me ask the questions, why are you doing that, how does that work, what does that tool do? I am sure it distracted him from getting the job done, but helped me find my love of cars and eventually get into mechanical engineering.

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Redesigning Reverse Engineering Curriculum

by

Nicole Howard, M.A.

The University of Texas at Austin, 2011

SUPERVISOR; Richard Crawford

Engineering curricula for high schools has and will become increasingly important as STEM (Science Technology Engineering and Mathematics) education matures and grows across the country. Active learning and hands-on pedagogies are critical to the development of these curricula, connecting students to the integrated topics using all senses and a commitment to self-learning. One approach to curriculum development for the Engineering, applied Science, and applied Mathematics in STEM is design-based learning (DBL). For this report, a particular methodology, known as Reverse Engineering and Redesign, is explored for DBL. The Reverse Engineering and Redesign process is used to redesign the current University of Texas' UTeach*Engineering* reverse engineering curriculum. The UTeach*Engineering* curriculum is compared to the

Engineering the Future, Ford PAS, The Infinity Project, and Project Lead the Way to determine the TEKS covered by each curriculum. The redesign focused on adding various writing and reflection exercises throughout the curriculum, and adding specification sheets and rubrics to all the student deliverables. The writing exercises are essential to allow the students to fully explore, comprehend, and appreciate the material. Specification sheets and rubrics are essential for the students to understand what is expected of them to attain mastery of the reverse engineering and redesign curriculum.

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Chapter 1: Introduction

The State of Texas House Bill 3 contains new requirements, such as schools shall "implement or administer a program that provides opportunities for students to take academically rigorous course work, including four years of mathematics and four years of science at the high school level." (Texas House Bill 2009, 131-132) In response to the bill, the Texas Education Agency (TEA) updated high school graduation requirements to include new fourth year science courses beginning in the 2010-2011 school year. The engineering science elective course was created and named Engineering Design and Problem Solving. The prerequisites for this course are completion of Geometry, Algebra II, Chemistry and Physics, and it is recommended for those students in 11th and 12th grades.

Many different types of engineering curricula are available for either purchase, through training or downloadable online. These include, Project Lead the Way, Ford PAS, The Infinity Project, and Engineering the Future. Project Lead the Way requires a substantial monetary commitment, recurring summer training commitment from teachers and three years of programs offered at the school. Ford PAS is downloadable online and free. Printed copies are available of each module in the curriculum for $48-$77 for teacher manuals and $18-$22 for student manuals. The Infinity Project requires one-time summer training for teachers, and purchase of textbooks and curriculum. Engineering the Future's materials are available for purchase, and there is online training available (not required).

In response to the change in the high school graduation requirements and to create a universally implementable Engineering Design and Problem Solving curriculum, The University of Texas (UT) at Austin has developed an alternative solution. A six week summer institute consisting of two courses, Fundamentals of Engineering and Design and Project-Based Lesson Development in Engineering, has been created to prepare teachers of the Engineering Design and Problem Solving fourth year science course. This institute has been offered at UT Austin, UT Dallas, and UT El Paso. A yearlong curriculum has been developed through the UTeach*Engineering* program covering energy, reverse engineering, robotics, ethics, team building and an open-ended capstone project. The curriculum was designed to provide students with an introduction to the engineering design process through a series of design experiences. “The goal is not that every student becomes an engineer, but rather that all students have opportunities to develop skills in the design process and team interaction, as well as the preparation in science, mathematics and technology.” (Petrosino, Svihla, and Nathan, 6) The UT curriculum uses the student’s previous knowledge from Physics, Biology, Chemistry, Algebra I & II, and Geometry to analyze engineered products and to design their own solutions to problems.

Reverse Engineering

Reverse Engineering is used throughout industry for dissecting engineering products to determine how they work. “This includes observing, disassembly, analyzing and testing the product and then documenting it in terms of its functionality, form physical principles, manufacturability, and assembleabilty.” (Zayad 1995, 3) Examples of products eligible for reverse engineering are rockets, automobiles, manufacturing processes, engineering 3D models, electronics and computer software.

Industry Application

While working at Pratt and Whitney Rocketdyne, one of the last projects I worked on was the Constellation project for NASA. This rocket was meant to replace the current Space Shuttle technology and go back to the design of astronauts located in a capsule. We were using the J2 upper stage engine from the Apollo rocket as the baseline for the new upper stage engine. Because of the time gap between the two projects, we had to use the methods of reverse engineering to determine how the engine was created. We had access to the engineering drawings which contained dimensions and some requirements. Although engineering information is located on the detail and assembly drawings, the manufacturing processes were not present on the drawings, and we did not have the engineering notebooks from the designers of the Apollo program. The thinking process an engineer typically goes through during a design cycle is not present on the drawings, and we used reverse engineering techniques to determine why features were created on a component.

Using the drawings from the 1960s, assembled engines, and a computer aided modeling program, we were able to recreate the engine in 3D. The 3D model was then used to create new 3D models and drawings to satisfy the new requirements from NASA.

Problem Statement

In this report, the UTeach*Engineering* reverse engineering unit is analyzed using the reverse engineering process, and the TEKS it covers are compared to those covered by other "out of the box" curricula. This investigation is conducted to solve the problem statement, using the reverse engineering process to redesign the UTeach*Engineering* high school reverse engineering curriculum.

Chapter 2: Reverse Engineering in the College Classroom

Universities are developing classes in their engineering education that focus on mechanical dissection. In these classes students take apart mechanical devices to determine the engineering behind each one: how it works, what materials were chosen, how it was manufactured, and what customer needs each function satisfies. Currently in most engineering programs students learn concepts in individual classes, such as mechanics, materials, and circuits. Offerings that include dissection projects provide a context for these individual and topic specific courses.

University of Wisconsin Madison

At the University of Wisconsin Madison, engineering students enroll in a Mechanical Dissection course. “During the class, students analyze the function, design, and manufacture of basic pieces of engineering equipment” (Eggert 1996, 1495). The structure of the class follows these steps: 1) Chalk Talk with the professor about the piece of equipment being dissected, providing background of the equipment, 2) Students dissect the equipment to subsystems (components), 3) Students break into teams to dissect components of the equipment, 4) Once students become an expert on their components, they rotate groups to obtain knowledge of the other components, 5) Students write a report that summarizes the entire dissection using free body diagrams, sketches, calculations, and answers to specific questions posed about the equipment. (Eggert 1996, 1497)

In the Mechanical Dissection course, students must draw the components of the object they are dissecting “to maintain a strong visual interpretation of the equipment” (Eggert 1996, 1497). This allows them to have documentation of the equipment that is available long after the dissection is over and to reflect on the process and topical content. As students are teaching each other concepts concerning their components and writing their final reports, the visual representations can be used as aids. The students are assessed based on “their ability to clearly relate their engineering knowledge to the equipment” (Eggert 1996, 1497) through their explanations to others and their reports.

Eggert also found that “classes not offering solid physical examples to explain their concepts often lose their effectiveness due to low student interest and, subsequently, low retention of the material taught.” (1495) Students are able to strengthen their prior knowledge and through the dissection process build new knowledge in relation to a real world engineering example.

Stanford University

Dr. Sheri Sheppard developed a course in mechanical dissection to answer the question “how did others solve a particular problem?” (Sheppard 1992, 2) Her course is used as a foundation course for freshman and sophomores studying Mechanical Engineering at Stanford University to provide them with more hands-on experience. The objectives of the Mechanical Dissection course are “Understanding of mechanical artifacts, Awareness of the design process, Power of clear, concise communications, and Resourcefulness and problem solving skills" (Sheppard 1992, 2).

The student deliverables for the mechanical dissection course are a 10 minute class presentation for the assigned artifacts, a term paper and participation in a poster session. In the presentation students explain what they "thought the designer's functional specifications were" (Sheppard 1992, 4) and compare the specification list with the functions of the component of the product.

Dr. Sheppard focuses on "learning the vocabulary of mechanical systems" (1992, 3). This approach provides scaffolding for the student to understand the fit, form and function of components such as bearings, bushings, bolts, and other types of standard parts used in the design of a functioning component. After the students discover these components during disassembly, lectures are given on each standard component.

University of Texas

At The University of Texas at Austin two undergraduate courses deal with reverse engineering and redesign: ME 202 Introduction to Mechanical Engineering and ME 366J Mechanical Engineering Design Methodology. According to Wood et al, in the ME366J course, there are three projects:

1. Part One - Something you've always wanted to do but never had the time.

Part Two - So how are you going to help me?

2. Original Design
3. Make it better! (2001, 367-370)

In this course students choose products to reverse engineer and redesign. During the first part of the first project, the students develop a black box, gather customer needs, create an activity diagram, create a functional model, and predict how the product works at a component level. The second part of the first project is a continuation of part one and students have the opportunity to disassemble their products. They create “a plan for disassembly, disassemble, create a bill of materials, create an exploded view, describe how the product works, compare predicted with actual workings of the product, consider flows in the black box, conduct research, create a house of quality diagram, include ranking of their product to competitors’ products, and determine what aspects of the product can be improved, i.e., innovative redesign avenues.” (Wood et al 2001, 370) In the second project students create an original design of a product using “the same methods to solve the original design problem as they learned through reverse engineering.” (Wood, et al 2001, 370) In this stage, contemporary ideation techniques are used by the design teams to generate hundreds of system and subsystem concepts for evolving the product design for both explicit and latent needs. In the third project, design teams apply their ideation results to their reverse engineering product and “decide how to achieve improvements, adapt alternative concepts, choose a concept, develop design models, calibrate models, conduct design of experiments on an evolved product prototype, revise the bill of materials, and conclude about the process." (Wood, et al 2001, 370)

Chapter 3: Applicable High School Pedagogy

Teaching engineering in a high school classroom cannot be delivered solely through lectures, notes and worksheets. “Active, hands-on activities are the real lessons.” (Kohn 1993, 211-212) The pedagogy used in the engineering classroom must match the hands-on, teamwork, and assignments that engineers face each day in industry.

Project Based Learning

Project based learning (PBL) is defined as “a systematic teaching method that engages student is learning knowledge and skills through an extended inquiry process structured around complex, authentic questions and carefully designed products and tasks.” (Markham, Larmer & Ravitz 2003, 4) The PBL lessons are created based on the state standards and are more exciting for a student to explore topics than simply listening to a lecture. Design-based activities “narrow achievement gaps in knowledge of science, technology, and engineering between high- and low-performing students by raising the performance of the lowest performing students.” (Petrosino, 11) As students work together in groups and share their knowledge, the low-performing students gain knowledge from their peers and/or from the process of solving a problem that excites their thinking, and the high-performing students activate an even higher level of thinking when teaching their peers.

Cooperative Learning

Cooperative Learning is more than just placing students in groups to complete an assignment. Students work together towards a common goal, where the tasks are shared and students are excited about completing a challenge. (Kohn 1992, 50-51) "Cooperative learning produced better results than individualized achievement in almost exactly the same proportion where there were significant differences." (Kohn 1992, 205) When the students are all successful, it provides the students with a positive learning experience.

Learning and the Brain

As the curriculum is designed and executed, it is important to understand how the brain gleans new information and recalls the information at a future time of need. Two important factors in information storage in the brain are the meaning to the student and the emotion felt at the time of learning.

Meaning and learning result in the following: "a sense of personal significance and importance is essential to learning." (Johnson 2011, 3) The curriculum must have a focus that the student finds engaging and has a curiosity to know more about the topic. Meaning for the student can also be a connection of an event or person to the subject of the curriculum. For example, if a student is learning about free body diagrams and the effect on cars in a crash, and if this student on the weekend likes to race cars, s/he would most likely find the topic more engaging than a student who must take the bus everywhere and cannot drive.

Students must also have an emotional attachment at the time of learning. Students can feel passionate about the topic of study or simply feel a sense of belonging in their group. This sense of belonging allows students to relax when faced with challenges or curriculum they are unfamiliar with. When students "feel connected to a social group, feel that they belong, the brain rewards them with a sense of pleasure." (Johnson 2011, 3) This sense of pleasure leads to enjoyment in the student's learning and retention of material.

Assessments

In high school engineering curricula, projects are introduced to students and, throughout the projects, tasks are completed that do not have a single, exact answer. When teachers "do not have a single, correct answer or solution process, evaluation of student work is based on judgment guided by criteria to determine the degree of understanding." (Wiggins and McTighe 2006, 172) Students need to know what criteria distinguish a good piece of work prior to completion of the task. One such method of providing these criteria is the scoring rubric. "Scoring rubrics are based on descriptive scales and support the evaluation of the extent to which criteria have been met." (Moskal 2000)

Rubrics can be powerful tools in the classroom as they make "teacher's expectations clear by showing students how to meet these expectations."

(Goodrich 1997, 2) Rubrics can also be used to self-assess or peer-assess assignments. “Repeated practice with peer assessment, and especially self-assessment, increases student’s sense of responsibility for their own work.” (Goodrich 1997, 2)

There are two types of rubrics, analytical and holistic. Analytical rubrics correspond to assessment criteria for individual assignments or components within a project. Holistic rubrics contain all parts of a project. For example, if a poster project is assigned to students about a branch of engineering, the analytical rubrics would be for the following tasks: research, poster, and the presentation. The holistic rubric would contain requirements that correspond to the student’s learning outcomes of the project. In other words did the student master the material? According to Wiggins and McTighe, “the quality of the feedback to the student is easily compromised in the name of efficiency when we boil down evaluation to a single (holistic score).” (2005, 174-175) They suggest a “rubric for ‘understanding’ and a rubric for the qualities of the ‘performance.’” (2005, 175)

Writing in the University Engineering Classroom

Writing in college engineering classrooms is essential because “writers are forced to think comprehensively and to link thoughts in sequence.” (Wheeler and McDonald 2000) Students can sometimes follow the mathematical sequence of solving a problem without understanding the meaning of each step. Writing assignments can enable the students to analyze their thought process of problem solving. Writing assignments do not have to be intrusive to the current curriculum. "Single paragraphs can be effective at facilitating the development of writing skills." (Woods, Felder, Rugarcia, and Stice 2000, 110) Creating reflection assignments when students are problem solving are beneficial to understanding the material they are learning.

A study by Wheeler, Balazs, and McDonald at Virginia Military Institute determined "those who write more are likely to write and communicate better than those who write less" (Wheeler et al. 1998, 238) in the engineering classroom. Wheeler added writing components to his electrical engineering courses starting with an assignment every two weeks. By the end of the semester his students had written six assignments. All of the assignments were individually graded for "logical content, clarity, and style" (Wheeler et al. 1998, 237) although there was no indication if a specification sheet or rubric was used in the assessment.

When polled in the middle of the semester, the students confessed that "the writing assignments allowed them to understand the subject material at a deeper level than they otherwise would have." (Wheeler et al. 1998, 237) It "forced them to think and to understand exactly what they wished to say and that, as a result, their understanding of the material was enhanced." (Wheeler et al. 1998, 237) Through the writing assignments, Wheeler was able to extend the student's knowledge from simply problem solving to problem solving with possible ethical or political issues that frequently accompany real-world engineering decision making.

At Southeast Missouri State University a program called The System, was created to assist teachers in assigning more discipline-specific writing in their engineering courses. “The teaching intent of each assignment is to assist students in the organization and development of their thoughts on paper.” (Boyd and Hassett 2000, 410) It was found that throughout the semester, students’ grades on papers improved as well as the amount of time a professor had to devote to grading.

The two components in the writing assignments are the rubric and the work order. The rubric contains the requirements for assessing the paper and is the same for every writing assignment. The rubric shows that feedback is based on use of the following detractors: “*I’s* excessively used, *sp*-consistently misspelled words, *use*-misused words, *format*-did not lay out the paper as requested, and *oops*-did not answer the question.” (Boyd and Hassett 2000, 411) The work order provides the format and the topic and specific questions each student is required to answer.

Chapter 4: Current Reverse Engineering Curriculum in High School

Students are naturally curious of how things work. Many of them want to dissect various objects around the classroom, within their everyday lives, and those they encounter in visual media, and determine how they work. They want to uncover the magic behind the mechanical and electromechanical device. It is not enough for them to be told how it works. Educators must take advantage of students' curiosity and provide them with means to satisfy this yearning to discover how things work.

Reverse Engineering a product is the perfect solution to satisfy the student's natural curiosity and apply the mathematics and science they have previously learned. According to Sheppard and Tsai, "early exposure should start well before the freshman year in college." (1992) With the rigorous requirements of high school graduation, students in Texas must take four years of mathematics and four years of science. A curriculum of Reverse Engineering and Redesign encompasses many of the Texas Essential Knowledge and Skills (TEKS) presented by TEA.

Engineering the Future Reverse Engineering Curriculum

The Boston Museum of Science created a curriculum called Engineering the Future "to help all students better understand the designed world and the wide variety of career paths a person might take in designing, manufacturing, maintaining, or using technologies." (ETF 2008, XV) The curriculum is available for purchase through Key Curriculum Press. It consists of a teacher guide, a student textbook and engineer notebooks for each project. Supplies to support the projects are available through AquaPhoenix Education. Training is also available through the website that guides users through the student engineering notebook and textbook, completing all the tasks with other teachers. This curriculum contains four modules:

1. *Project 1.0 Design the Best Organizer in the World* – Students design an organizer for a company and learn how technologies are developed and manufactured.
2. *Project 2.0 Designing a Building of the Future* – Students explore materials and design a building for the 21st century.
3. *Project 3.0 Improve a Patented Boat Design* – Students reverse engineer a Putt-Putt- boat and make improvements to write their own patent.
4. *Project 4.0 Electricity and Communication Systems* – Students explore electricity and how it can be used for lighting, communication, and other purposes.

The engineering notebook created for students in this course is pre-printed, where students are expected to write in the books and keep the pages in a 3-ring binder with any additional sheets they use to answer questions from the textbook.

Project 3.0: Improve a Patented Boat Design is broken down into several different tasks the students need to complete to follow the whole reverse engineering process. Before beginning the tasks, students are placed in teams which contain co-leaders and the teams determine the outcomes of the teamwork. The tasks are described below.

Task 3.1: Putt-Putt Boats and Patents

Students read a patent from England for an improvement in steam generators. This patent explains to students how his engine design works using a model boat. Next the students watch a model of the putt-putt boat in a pool of water and try to determine how it works. After the demonstration of the putt-putt boat, students write how they would like to improve the boat and categorize it by form or function. To make these improvements students determine what science or mathematics concepts they might need to know to redesign the putt-putt boat.

Task 3.2: Manufacture a Putt-Putt Boat

In this task, students make a putt-putt boat design out of milk cartons, soda cans, and straws. Students make the boiler out of an empty soda can, two flexible straws and epoxy. Safety is especially important in this step because the cut aluminum is extremely sharp. The hull is then constructed out of milk, juice, or soy milk cartons and staples using a utility knife. The directions for the boat are available to the students in their engineering notebook and online at www.sciencetoymaker.com with color pictures and videos. Because this task must be completed over several days, it is recommended that students continue with other tasks while waiting for epoxy and silicone to set. Students then read chapter 17 in the textbook which explains the definitions of fluids, pressure, compressible and incompressible fluids, buoyant force, and hydraulic systems through the story of the Alvin, a deep-sea vehicle that carries passengers.

Task 3.3: Investigate Fluid Systems

Students begin investigating open and closed fluid systems with syringes and aquarium tubing. They learn about hydraulic and pneumatic systems by putting water and air into a syringe with a cap and discover the effects of pushing and pulling on the piston. Students code fluid pressure in the syringes at various locations of the piston. To indicate the amount of pressure they use the following colors: red (the highest), orange, yellow, green, and blue (the lowest). After this task, students read chapter 19 in the text about a NASA engineer working on a Mars mission to bring back samples from the planet. Students learn how a rocket works, about Newton's 3rd Law of Motion, and about resistance-free travel in space and Newton's 1st Law of motion. They also learn the importance of testing in engineering to avoid failure in the field.

Task 3.4: Develop a Manufacturing Process

In this task, students design a brake press using either a hydraulic or pneumatic system. To get to the design, students first examine and make observations about a pneumatic system with various sizes of syringes and tubing. Students use Boyle's law to solve a pressure problem. Students then build a pneumatic pump using a syringe, two one-way valves, and a balloon. Students learn about one-way valves and explore the energy differences in pressure as the piston moves in the syringe. Next, students read Chapter 19 in the text, about converting a diesel car into a biodiesel vehicle. Throughout the chapter, students learn about the cycle of a diesel engine and the differences between gasoline and diesel.

Students then experiment with hydraulic systems by connecting two syringes with a tube filled with water. Students make observations about the difficulty of pushing a syringe within the system. Pascal's law is used to solve problems and look at pressure and forces in systems as well as how a hydraulic lift functions.

Students use the knowledge they have obtained throughout the task to design a brake press. They draw the parts they need to add using labels to identify the components and explain in writing why they chose the system.

Task 3.5: Investigate Heat Engines

Students watch the workings of an example of an acetone engine and write down their observations for each step. Students then color code the steps as they have done previously and describe what is happening to the pressure at each step. Boyle's, Charle's, Guy-Lussac's, and the combined gas laws are introduced so students can make the connections between science and engineering. Students use this information when observing the drinking bird toy, which contains methylene chloride, to determine how it continues to bob up and down, appearing to drinking water.

Students read chapter 20 in the text about the IBOT Mobility System which uses a Stirling engine to move. They learn that the Stirling engine is a closed system with the following components: heat source, working fluid, piston, crankshaft, and heat sink. Students also learn the types of gasses that would work well in the Stirling engine. After reading, students revisit the Otto cycle strokes and how a spark plug fits into the gasoline combustion system.

Chapter 21, the next reading in the text, explores geothermal systems to help solve the world's energy crisis. Within this chapter, students learn how turbines work and about renewable energy and geothermal plants in the United States. Students now revisit their constructed putt-putt boat and determine the steps in their boat's engine cycle, describing what is happening in each one.

Students take a benchmark assessment on the various engine cycles they have studied.

Task 3.6: The Rocket Effect

Students observe a pressurized water toy rocket and describe their thoughts on how it works. They test the water rocket using smaller and larger amounts of water to observe the differences and learn Newton's 2nd Law of Motion. Students then compare and contrast the rocket engine with the Piot engine from their putt-putt boat. They explore the rocket effect using syringes, tubing, and a basin filled with water. Students discover the effects of different diameters of tubing as water is being pushed through it while recording their observations. They try blowing a candle out with a straw and then extinguishing it by sucking in on the straw. They use this information to revisit the steps in their boat's engine and determine what is happening. Then they read Chapter 22, which explores nuclear reactors and revisits chemistry concepts.

Task 3.7 Investigate Resistance in Pipes

Students explore the resistance in pipes using straws with varying diameters, lengths, and quantities by recording the time to completely exhale through each type of straw. Student answer questions about what they discovered in experimenting with the straws and how it would affect their boat engine. They read Chapter 21 in the text which discusses environmental engineering and water flow in cities. Students learn about hydrostatic pressure, resistance in pipes, and the relationship between velocity and area in pipes.

Task 3.8: Redesign the Putt-Putt Boat

Students redesign any aspects of the putt-putt boat. They follow the redesign process by performing the following steps in teams:

- Define the problem(s) of the current design
- Write down what they have learned in the curriculum up to this point that could help out the team
- Determine possible customers and customer needs
- Brainstorm ideas
- Choose the best solution
- Create a prototype of their solution
- Test the new putt-putt boat design and evaluate
- Present their new design to the class

Task 3.9: Present Your Patent

Students are given an outline to individually create a patent for their improved putt-putt boat. The information that should be on their patent is similar to that found on Piot’s engine improvement: abstract, declaration, and specification. A rubric is provided at the end of the engineering notebook to guide the students in their requirements for their patent.

Ford PAS Reverse Engineering High School Curriculum

Ford Partnership for Advanced Studies (PAS) created an engineering curriculum for middle school and a separate curriculum for high school. One of the expected outcomes of the Ford PAS curriculum is “students will be college- and career- ready, a particular benefit for less-advantaged students who need to simultaneously work and pursue postsecondary education”. (FordPAS 2003) The curriculum is split into 20 modules:

1. *From Concept to Consumer: Building a Foundation in Problem Solving* – students explore the manufacturing process
2. *Media and Messages: Building a Foundation of Communication Skills* – students explore communication challenges in a company’s new venture
3. *People at Work: Building a Foundation in Research Skills* – students explore how immigration, the economy, technology, war and legislation affect people’s work
4. *Careers, Companies, and Communities* – students explore interdependency between communities and the workplace
5. *Closing the Environmental Loop* – students explore the various ways that the environment is affected by companies and products
6. *Planning for Efficiency* – students explore efficiency in business to meet customer demands

7. *Planning for Business Success* – students explore concepts of marketing and financial decision-making
8. *Ensuring Quality* – students explore statistics in engineering companies
9. *Data to Knowledge* – students explore skills to assist with decision making processes
10. *Reverse Engineering* – students explore several different types of reverse engineering in industry
11. *Different by Design* – students explore the redesign process
12. *Energy for the Future* – students explore alternative energy sources
13. *The Wealth of Nations* – students explore environmental, political, and social factors when determining where to place a factory
14. *Markets without Borders* – students explore the interdependency of the world market
15. *Global Citizens* – students explore the social and environmental issues that companies face
16. *Calculating your Future: Personal Finance* – students explore algebra concepts to understand the relationship between time and money
17. *We All Run on Energy* – students explore global challenges related to energy
18. *Energy from the Sun: Biomass* – students explore biomass in a country were citizens use biomass as a cooking fuel

19. *Is Hydrogen a Solution*? – students explore hydrogen energy by determining if it is a good investment for a company
20. *The Nuclear Revolution* – students explore using alternative energy in a European country

Each of these modules can be used independently and in any classroom environment. The modules are available online at www.fordpas.org and can be downloaded by teachers free of charge when they sign up at the website. Along with the modules the Ford PAS contains supporting documents for each activity. Some of these supporting documents are the teacher overview, student introduction, before you teach, skill resources, audio files, video files, homework, extensions, and reproducible masters. Rubrics are also available on these pages to assist teachers in assessing student assignments. The benefits of the Ford reverse engineering curriculum are that it is free to teachers, uses items that are inexpensive, and easy to implement in the classroom. At the end of each activity there are usually one or more extension activities.

Ford PAS recommends teachers have students use an engineering notebook throughout any of the modules. The specifications of the engineering notebook are that it should have the following features:

- Has a binding (like a composition notebook)
- All writing is in pen
- A single line is drawn through errors

- Preferably with graph paper (if not graph paper can be glued in where needed)
- Contains dated entries
- Assignments completed on separate paper should be pasted in the notebook

Module 10: Reverse Engineering curriculum contains the following activities

Activity 1: Design Detectives

In the Reverse Engineering Module students start off as interns in Gadget King, a fictitious company that designs and produces small kitchen appliances. Students begin the reverse engineering process looking at competitors' products and determine why they were designed in a particular manner. Students work in groups to discover the features that perform the functions of the various can openers. Students then determine secondary functions and decide which can opener works better. They determine the customer base (child, senior, etc.) for each can opener. Their first homework assignment is to rank all the can openers they have looked at for one customer base and write a memo to the head of operations about the perfect can opener for that customer base.

Students search in their classroom for products that may or may not have features for users who are left-handed, short, tall or need a wheelchair. Students fill out a Usability Checklist to rate the products. Students then create teams where there is a leader, recorder and timekeeper. The team leader creates agendas and presides over meetings.

Activity 2: Sizing up the Competition

Students are now placed into Gadget King's cups and container department. The reverse engineering process starts as students analyze Gadget King's competitors' sippy cups. They look at two different types, the starter sippy cup and the big kid's sippy cups. Students estimate the number of components in the sippy cup and how many steps it would take to assemble. Then they read an article on Design for Ease of Assembly and determine what features their new sippy cup design should contain. Students then create a memo to the heads of Gadget King describing which type of sippy cup was chosen to be produced and which features should be included in that design.

Activity 3: How'd They Make That?

The next department students explore in Gadget King is the gadgets and gizmos department, where they learn about manufacturing processes. Students are given a kitchen gadget to reverse engineer and determine the best manufacturing process (new or current) for the device. At the end of the activity students present their process proposals, which include results of the following tasks: describe material and processes to manufacture the product, show that a different process can be used, look at one different material which could be used, recommend a process to use to make the product, and explain how reverse engineering factored into the final recommendation. (Ford PAS 2011, 26)

Design teams use the Ford PAS website to research forging, casting, machining, blow molding, extrusion, injection molding, press working, and sintering. Students then need to determine raw materials, manufacturing process used, shape produced, job skills required, and advantages and disadvantages based on their kitchen gadget. Students then create a flow-process diagram for their process proposal project of their gadget. At this point in the curriculum Ford PAS suggests taking the students on a tour of a manufacturing facility.

Activity 4: A Failure to Communicate

Students create drawings and instructions for assembly and improve process instructions. Students create a structure out of building toys, such as LEGOs, and record the assembly steps. Students draw a 3D sketch of the assembly, name each part, sketch each part, and create assembly procedures. Teams then switch assembly instructions and the disassembled LEGOs and try to build another team's structure with their instructions. In the next step, students assemble a kit consisting of plastic pieces and analyze the assembly instructions that come with the kit. For homework, the students create an assembly drawing of a common object consisting of a minimum of 10 different parts and create a list of ways that product assembly can be communicated. Students read about the collapse of the Quebec Bridge in 1907 which happened because of a misalignment of the girders.

Activity 5: Failure Detectives

Students are introduced to several types of engineering material failures. Students are asked to determine which of the failure types caused the failure of the Quebec Bridge. They go to the Ford PAS website to research various failed components and then read about how stuff breaks. Students explore properties and failure modes of both metals and plastics. In a homework assignment, students explain how to test for fatigue or corrosion and then list uses where plastic is a better fit than metal. Students create an experiment and then test the failures of various metals and plastics due to bending. At the end of the activity students are introduced to composite materials and their benefits.

Activity 6: The Ethics of Failure

In this activity students explore the ethics of the failure of the Space Shuttle Challenger. They read about engineering ethics and why it is important to determine the cause of a failure. Students read about how the evidence was collected from the Challenger disaster and how it was reverse engineered to determine a cause. To complete a similar exercise students are placed into groups and given clay pots. In their groups they smash the clay pot and leave the pieces where they come to rest. They groups change locations of clay pots and create a site map to show where all the pieces are located. The teams try to determine the location of the smash site and report their findings to the original team.

The Infinity Project

"The Infinity Project was developed in 1999 by The Caruth Institute for Engineering Education and Texas Instruments with the U.S. Department of Education and the National Science Foundation." (The Infinity Project 2011) The Infinity Project is a complete engineering package that contains curriculum, textbook, and a technology kit. The Infinity Project has various curricula designed for grades 6-12 and early college students. The high school curriculum was designed for those who have completed Algebra II and at least one science course. The four modules in that curriculum are:

1. *Engineering Our Digital Future* –explores the fundamentals of engineering and technology in the information and communications age.
2. *The Challenge of Roving Callisto* – focuses on engineering principles necessary to create and design a robot to roam the surface of one of Jupiter's moons.
3. *Engineering Earth* – utilizes science, technology, and math to support human needs and develop ecological solutions.
4. *The Human Machine* – links biology, physics, chemistry and math together to investigate and improve the human condition. (The Infinity Project 2011)

Currently The Infinity Project contains no modules or projects on reverse engineering. In 2001, the Infinity Project received curriculum approval from the state of Texas and Engineering: The Digital Future was given its own course number and counts as a mathematics, science, or career and technology credit. There is no information on their website as to the status of the course following the new requirements (TEKS) for the fourth year science course, Engineering Design and Problem Solving. The Infinity Project curriculum is proprietary, and therefore unavailable to analyze.

Project Lead the Way: High School Engineering Program

Project Lead the Way (PLTW) High School Engineering Program is an engineering curriculum consisting of several year-long courses. The program requires a school or district to agree to their standards and costs, which are dependent on “which courses are being taught, how many sections of each course are being implemented, and what you already have in your classroom/lab” (Project Lead the Way 2011). Teachers are provided with training at one of their sites on a yearly basis, the complete curriculum based on National Standards, including online support, and end of course assessments. According to their website, “Each course curriculum represents a complete package, which allows the instructor to focus on teaching student achievement, assessment, and professional development. (Project Lead the Way 2011)

Schools that offer four or more classes are eligible to be certified by PLTW. If schools offer three or fewer classes, they are not eligible for certification, but are still subject to quality control inspections by Project Lead the Way. Teachers interested in teaching any of the courses must be trained by Project Lead the Way and are only required to have a bachelor's degree and a state teaching license.

"PLTW classes are hands-on, based in real-world experience, and engaging for students and teachers" (Project Lead the Way 2011) The Introduction to Engineering Design (IED) course is targeted to 9^{th} and 10^{th} graders. In 2010, this course was revamped and an entire module was created for Reverse Engineering. Project Lead the Way curriculum is proprietary, and therefore unavailable to analyze.

UTeach*Engineering* Reverse Engineering and Redesign Curriculum

The University of Texas at Austin created a curriculum for the high school TEKS of the Engineering and Problem Solving fourth year science course. A training course is offered during the summer for teachers who will be teaching the course. The curriculum was developed in collaboration with the and teachers in Austin ISD. The curriculum was created for classes that run 50 minutes 5 days a week.

Day 1: Introduction to Reverse Engineering and Redesign

Students are introduced to devices such as a can opener, flashlight, or alarm clock. Students are asked about issues involved in the design of the device, what could be improved about the device and how could they can improve the device. Students then watch the Deep Dive video about IDEO, a company that redesigns the shopping cart. A PowerPoint presentation is given about reverse engineering and gathering customer needs. Reverse engineering a hair dryer is introduced and students are given homework to interview different people about the hair dryer using the Interview Worksheet.

Day 2: Interpreting Customer Needs

Students share the results of their interviews in class and are given a presentation about the importance of customer needs and interpreting their collected customer needs. They brainstorm other ways to get customer feedback besides interviewing. Student then assemble in groups to interpret the customer statements they collected for homework and conduct an affinity analysis. In the affinity analysis the students group the customer needs together into main categories such as safety and performance. The interpreted needs are recorded by the class into a large table.

Day 3: Creating Specifications

Students are given a presentation on specifications. As a class the specification sheet is created from the interpreted needs table from Day 2.

Day 4: Hair Dryer Measurement – Power Input

Students determine the electrical power input to the hair dryer by measuring voltage into the hair dryer and the current drawn by the hair dryer as it is used. Prior to taking the measurements a PowerPoint presentation is given to explain the measurements, equipment and how to determine electrical power. These measurements are taken for each setting on the hair dryer (hot, warm, and the cool shot button)

Day 5: Hair Dryer Measurement – Power Output Notes

Students are presented with a PowerPoint about measuring power output on the hair dryer. They learn how to measure and calculate heat flow, volumetric flow rate, air speed, and mass flow rate.

Day 6: Hair Dryer Measurement – Calculating Power Output

In groups, students measure and calculate power output of the hair dryer on each setting by measuring: ambient air temperature, temperature out, speed of the air flow, and diameter of the exit nozzle.

Day 7: Hair Dryer Measurement – Determining Efficiency and Dry Time

Students are given a PowerPoint presentation on calculating efficiency of the hair dryer. They then use their data from days 5 and 6 to perform the calculations. Next students measure the time it takes for a wet paper towel to dry when the hair dryer is blowing at each setting.

Day 8: Predictions of Inner Workings

Students learn about functional modeling and are presented a PowerPoint on the black box diagram. The black box diagram is created either with the whole class, or in their groups. Students explore inputs and outputs with their black box diagrams. Then they sketch their predictions for the inner workings of the hair dryer.

Day 9: Predictions of Internal Workings

Day 9 is a continuation of predictions of internal workings of the hair dryer. Students are introduced to the activity diagram on a PowerPoint. As a class, students create an activity diagram for the hair dryer. They break down the steps a user would go through when using the hair dryer and place them on the activity diagram. Then the students are shown a function tree and as a class they create one for the hair dryer. The black box diagram is decomposed into subfunctions to create the function tree for the hair dryer.

Day 10: Product Disassembly Part 1

Students begin disassembly while photographing parts and writing down steps in as they take apart the hair dryer. Students try to figure out the functions of components in the hair dryer.

Day 11: Product Disassembly Part 2

Students continue working in their teams to finish disassembling the hair dryer. Students answer questions about the process of disassembly and the structure and function of the hair dryer.

Day 12: Redesign Challenge

Students try to determine what each component does in the hair dryer. A class discussion is held about the form and functions of various components in the hair dryer. Students come up with questions about functions of components to ask the manufacturer of the hair dryer.

Day 13: Redesign Challenge

Students revisit their diagrams for functional modeling now that they have disassembled the hair dryer. If there are any changes to these students should update their functional models. Students then brainstorm ideas for redesigning the hair dryer.

Day 14: Redesign Challenge

Students explain how the documented disassembly process can help in reassembly. The create a large drawing to show disassembled parts, labeling all parts and drawing arrows to show steps. Students look at assembly instructions for new products.

Day 15: Product Redesign

Students brainstorm ideas to redesign a common household item such as a hairbrush. They write their ideas down on post-it notes. A presentation on engineering redesign is given, discussing the differences between parametric, adaptive and original redesign. Students are informed of the challenge they face of redesigning their hair dryer. Homework is assigned to generate ideas for redesigning the hair dryer.

Days 16-17: Concept Generation

A class discussion is held about how students generated ideas for homework. Students are given a PowerPoint presentation on the brainstorming process and create a mind map of their ideas to help create new ideas. Students determine the importance of creating several ideas to redesign and then decide if it is helpful to use historical references in the redesign process.

Days 18-19: Timeline of Innovation

Students use historical references and research the various stages in the development of the hair dryer from 1890 – Present. Students individually or in a group create a timeline of innovation for the hair dryer and especially look for the whys of advancements. For example, they explore the underlying scientific or technological advances that occurred to allow improvements in hair dryers. Students record notes in their engineering notebooks on findings in development of technology in hair dryer advancements.

Day 20: Concept Selection

Students chose a concept to develop. They are introduced to concept selection techniques through a PowerPoint presentation. They create a Pugh chart for their ideas and compare concepts based on the specifications created earlier in the project.

Days 21-23: Redesign Challenge Presentation

Students create a PowerPoint presentation discussing the outcome of the redesign (new version of product) and the redesign process. Students use brainstorming to select documents to be placed in the presentation using Post-It notes to categorize on a poster board. The various groups observe other teams' poster boards to get ideas for their own projects. On the third day, students present their work on the challenge and their redesign. A presentation grading rubric is handed out to students for peer review of presentations.

Day 24: Redesign Challenge Wrap-Up

Students reflect on the reverse engineering and redesign process. They focus on the challenge, teamwork, and presentations. It is suggested that this be done both as a team discussion and individually.

Chapter5: Redesigning the UTeach*Engineering* Curriculum

The process used to redesign the UTeach*Engineering* Curriculum is the same process as that found in the UTeach reverse engineering and redesign curriculum. A customer analysis is performed to determine if the needs exists to redesign the curriculum. Functional models are created to determine the process of reverse engineering and determine if the current model satisfies the needs. Research is completed on several different reverse engineering curricula available to high school teachers to determine the effectiveness of the UTeach*Engineering* model. Each of the reverse engineering curricula is dissected to determine which of the TEKS are addressed. Then the UTeach*Engineering* curriculum is redesigned based on the findings from the customer needs, functional modeling, and curriculum dissection.

Reverse Engineering and Redesign Process

The reverse engineering and redesign process used for this project is the same process in the reverse engineering curriculum presentation. The steps of the reverse engineering and redesign process are: understanding the opportunity for redesign, quantification of need, and concept engineering. Understanding the opportunity is determining if there is a need for the product and if so what redesign possibilities exist. Quantification of the need is testing the product and if applicable comparing it to other similar products in the market. The concept engineering process consists of redesigning the current product to fit new customer needs or enhance the current ones. The reverse engineering and redesign flow chart is shown in Figure 1.

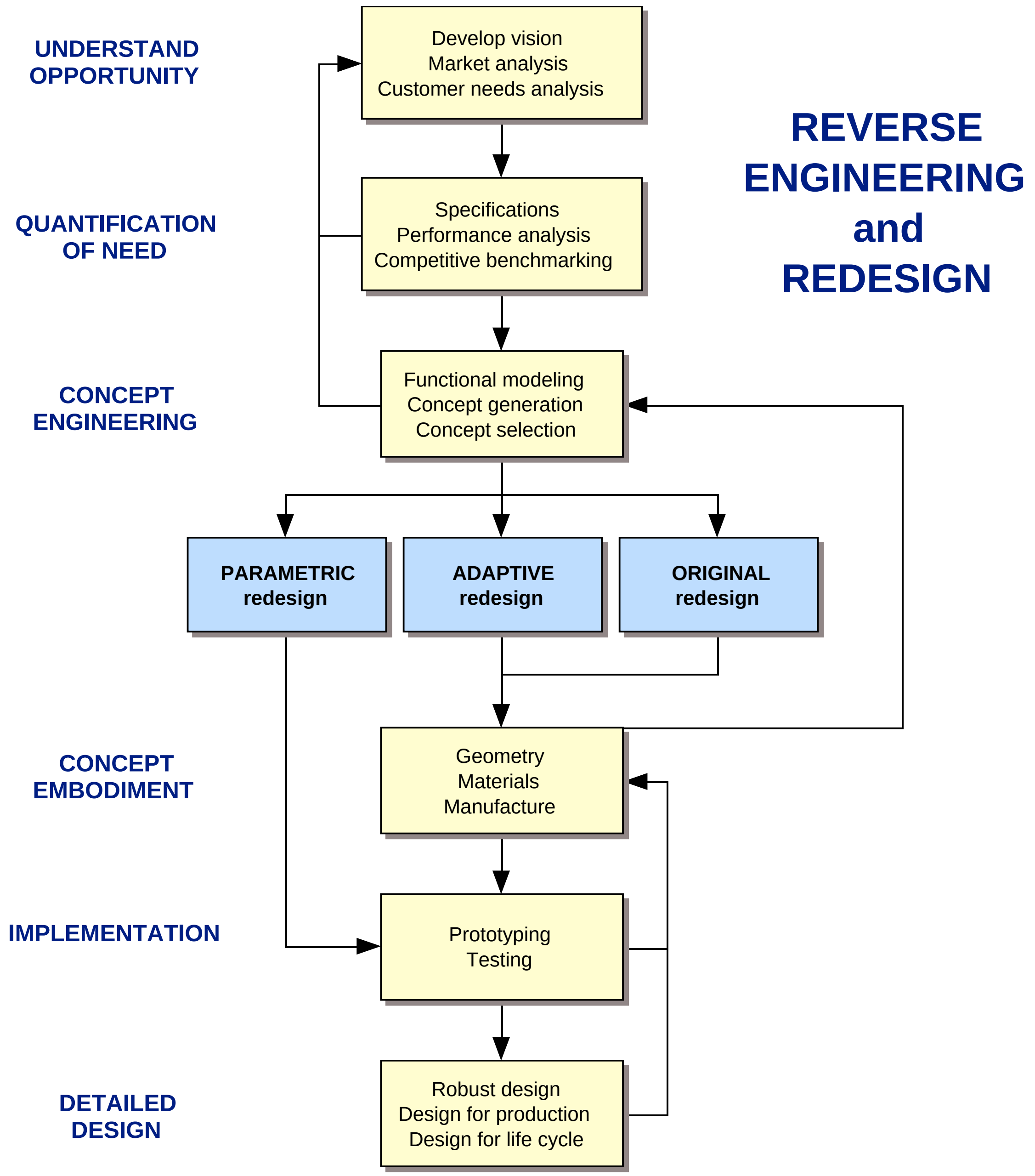

Figure 1: Reverse Engineering and Redesign Process (UTeach*Engineering* curriculum)

Understanding the Opportunity

Why reverse engineer the UTeach*Engineering* reverse engineering and redesign curriculum? In the state of Texas, the school year 2010-2011 was the first year the Engineering Design and Problem Solving course was offered. The UTeach*Engineering* curriculum was used in several classrooms across the state. With one year complete, it is a good time to revamp the current curriculum to add what is was missing from its debut. The purposes of reverse engineering curricula in high school: are

- Generate student interest in engineering
- Satisfy student interest in how things work
- Provide an increase in knowledge retention and understanding of Mathematics and Science by providing application for what was learned their freshman and sophomore years
- Allowing students to get a "feel" for magnitude of measured values

Customer Needs Analysis

The customers for the redesign of the UTeach*Engineering* reverse engineering curriculum are teachers of the Engineering Design and Problem Solving course. The customer needs were created based on information gathered from informal conversations with teachers currently teaching the course or who have previously attended the Engineering Summer Institute for Teachers

(ESIT) training at UT Austin. The customer needs are recorded in Table 1 and ranked in order of importance.

Customer Requirements
Ease of Use
Obtainable products
Measurement tools
Clear teacher instructions
Clear student expectations
Implementation in classroom
Robust Curriculum
Applicable to a variety of products
Student friendly
Easy to adjust for various student populations
Cost
Affordable Training
Materials under $2000
Safety
Materials are safe for high school environment

Table 1: Reverse Engineering Customer Needs Analysis

Ease of Use is the most important aspect for teachers to feel comfortable adapting a new curriculum, especially if it is one that is not in their area of study. The current process consists of teachers going to training during the summer to learn the process of reverse engineering with other teachers, attending another training session prior to teaching the reverse engineering project and obtaining the curriculum, both hard copy and online.

Quantification of Need

In the UTeach*Engineering* curriculum, this is the phase of the process where the product is tested and disassembled. For this report the curriculum, the product, is tested in comparison to other curricula available to high school teachers: Engineering the Future, Ford PAS, The Infinity Project, Project Lead the Way, and UTeach*Engineering*.

Comparison of TEKS for High School Reverse Engineering Curriculum

A comparison chart was created to show the different Texas Essential Knowledge and Skills that are covered by the Ford PAS, Engineering the Future and UTeach reverse engineering curriculum. Table 2 shows the TEKS addressed by each of the reverse engineering curricula.

Reverse Engineering is one component of the entire Engineering Design and Problem Solving course. The TEKS that are not covered in this project can be easily integrated into an introduction to engineering project and a final design project, where students learn about teaming and working together. Two of the TEKS can be added to the current reverse engineering unit by having the students examine a patent for an early model hair dryer:

> *3(B) read and comprehend technical documents, including specifications and procedures*
>
> *4(F) describe the importance of patents and the protection of intellectual property rights*

Engineering TEKS	Ford PAS	Engineering the Future	UTeach Engineering
(1) The student, for at least 40% of instructional time, conducts engineering field and laboratory activities using safe, environmentally appropriate, and ethical practices. The student is expected to:			
(A) demonstrate safe practices during engineering field and laboratory activities; and	X	X	X
(B) make informed choices in the use and conservation of resources, recycling of materials, and the safe and legal disposal of materials	X	X	X
(2) The student applies knowledge of science and mathematics and the tools of technology to solve engineering design problems. The student is expected to:			
(A) apply scientific processes and concepts outlined in the Texas Essential Knowledge and Skills (TEKS) for Biology, Chemistry, or Physics relevant to engineering design problems	X	X	X
(B) apply concepts, procedures, and functions outlined in the TEKS for Algebra I, Geometry, and Algebra II relevant to engineering design problems;		X	X
(C) select appropriate mathematical models to develop solutions to engineering design problems		X	X
(D) integrate advanced mathematics and science skills as necessary to develop solutions to engineering design problems			
(E) judge the reasonableness of mathematical models and solutions			
(F) investigate and apply relevant chemical, mechanical, biological, electrical, and physical properties of materials to engineering design problems	X		X
(G) identify the inputs, processes, outputs, control, and feedback associated with open and closed systems		X	X
(H) describe the difference between open-loop and closed-loop control systems		X	X
(I) make measurements and specify tolerances with minimum necessary accuracy and precision			X
(J) use appropriate measurement systems, including customary and International System (SI) of units			X
(K) use conversions between measurement systems to solve real-world problems			X
(3) The student communicates through written documents, presentations, and graphic representations using the tools and techniques of professional engineers. The student is expected to			
(A) communicate visually by sketching and creating technical drawings using established engineering graphic tools, techniques, and standards	X	X	X
(B) read and comprehend technical documents, including specifications and procedures;	X	X	
(C) prepare written documents such as memorandums, emails, design proposals, procedural directions, letters, and technical reports using the formatting and terminology conventions of technical documentation	X	X	X
(D) organize information for visual display and analysis using appropriate formats for various audiences, including, but not limited to, graphs and tables	X	X	X
(E) evaluate the quality and relevance of sources and cite appropriately			X
(F) defend a design solution in a presentation	X	X	X

Table 2: Comparison Chart of TEKS for Reverse Engineering Curriculum

Engineering TEKS	Ford PAS	Engineering the Future	UTeach Engineering
(4) The student recognizes the history, development, and practices of the engineering professions. The student is expected to			
(A) identify and describe career options, working conditions, earnings, and educational requirements of various engineering disciplines such as those listed by the Texas Board of Professional Engineers	X	X	
(B) recognize that engineers are guided by established codes emphasizing high ethical standards	X		X
(C) explore the differences, similarities, and interactions among engineers, scientists, and mathematicians			
(D) describe how technology has evolved in the field of engineering and consider how it will continue to be a useful tool in solving engineering problems	X		X
(E) discuss the history and importance of engineering innovation on the United States economy and quality of life	X	X	X
(F) describe the importance of patents and the protection of intellectual property rights		X	
(5) The student creates justifiable solutions to open-ended problems using engineering design practices and processes. The student is expected to			
(A) identify and define an engineering problem		X	X
(B) formulate goals, objectives, and requirements to solve an engineering problem		X	
(C) determine the design parameters associated with an engineering problem such as materials, personnel, resources, funding, manufacturability, feasibility, and time		X	
(D) establish and evaluate constraints pertaining to a problem, including, but not limited to, health, safety, social, environmental, ethical, political, regulatory, and legal	X	X	
(E) identify or create alternative solutions to a problem using a variety of techniques such as brainstorming, reverse engineering, and researching engineered and natural solutions	X	X	X
(F) test and evaluate proposed solutions using methods such as models, prototypes, mock-ups, simulations, critical design review, statistical analysis, or experiments	X	X	
(G) apply structured techniques to select and justify a preferred solution to a problem such as a decision tree, design matrix, or cost-benefit analysis			X
(H) predict performance, failure modes, and reliability of a design solution			
(I) prepare a project report that clearly documents the designs, decisions, and activities during each phase of the engineering design process			
(6) The student manages an engineering design project. The student is expected to:			
(A) participate in the design and implementation of a real or simulated engineering project	X	X	X
(B) develop a plan and timeline for completion of a project			
(C) work in teams and share responsibilities, acknowledging, encouraging, and valuing contributions of all team members	X	X	X
(D) compare and contrast the roles of a team leader and other team responsibilities	X		
(E) identify and manage the resources needed to complete a project			
(F) use a budget to determine effective strategies to meet cost constraints			
(G) create a risk assessment for an engineering design project			
(H) analyze and critique the results of an engineering design project			X
(I) maintain an engineering notebook that chronicles work such as ideas, concepts, inventions, sketches, and experiments	X	X	X

Table 2: Comparison Chart of TEKS for Reverse Engineering Curriculum (cont'd.)

Concept Engineering

The concept engineering part of the reverse engineering process is creating models of the product to be studied and dissected. These models include the black box, function tree, and activity diagram of the reverse engineering curriculum.

Black Box

The Black Box model is created to describe the external input and output flows to the product being analyzed. It removes features associated with the product which may lead to a specific design solution. In the center of the box the overall function of the system is stated. “By doing so, an ‘unbiased’ perception of the possible product evolution is maintained, in addition to avoiding psychological inertia when generating concepts in later stages of the (reverse engineering) methodology.” (Otto and Wood 1998, 229) For example, the goal of the coffee maker is to brew coffee. The input and output flows include energy flows, represented by thin arrows; material flows, represented by thick arrows; and signals or information flows, represented by dashed arrows. Examples of energy inputs and outputs are electricity or human energy. Examples of the material flows are wood for a saw or coffee for a coffee maker. Examples of information flows are any buttons the user may push and a sound to let the user know the function is complete.

A black box model was created showing the process of a reverse engineering curriculum.

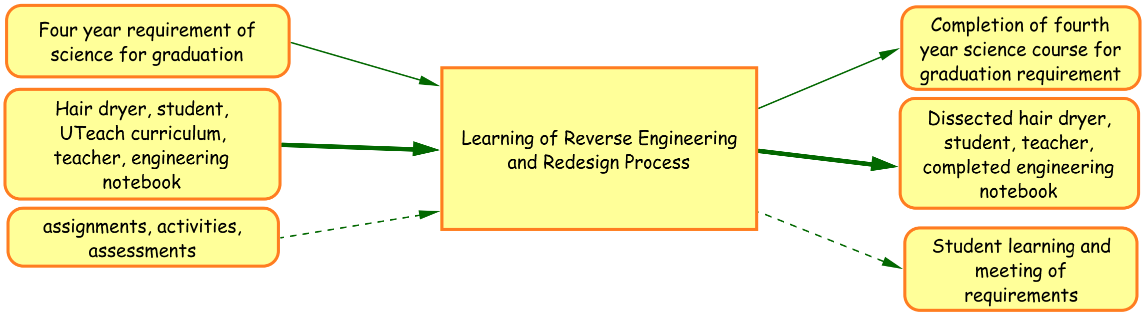

Figure 2: Reverse Engineering Black Box

Function Tree

A function tree is “a hierarchical diagram that identifies what a product must do.” (UTeach*Engineering* Curriculum 2010) Similar to the black box model, the function tree begins with the overall function of the system and uses the flows from the black box model as the start of each interdependent activity. In the process of the reverse engineering and redesign curriculum, each strand is based on the inputs and outputs from the black box.

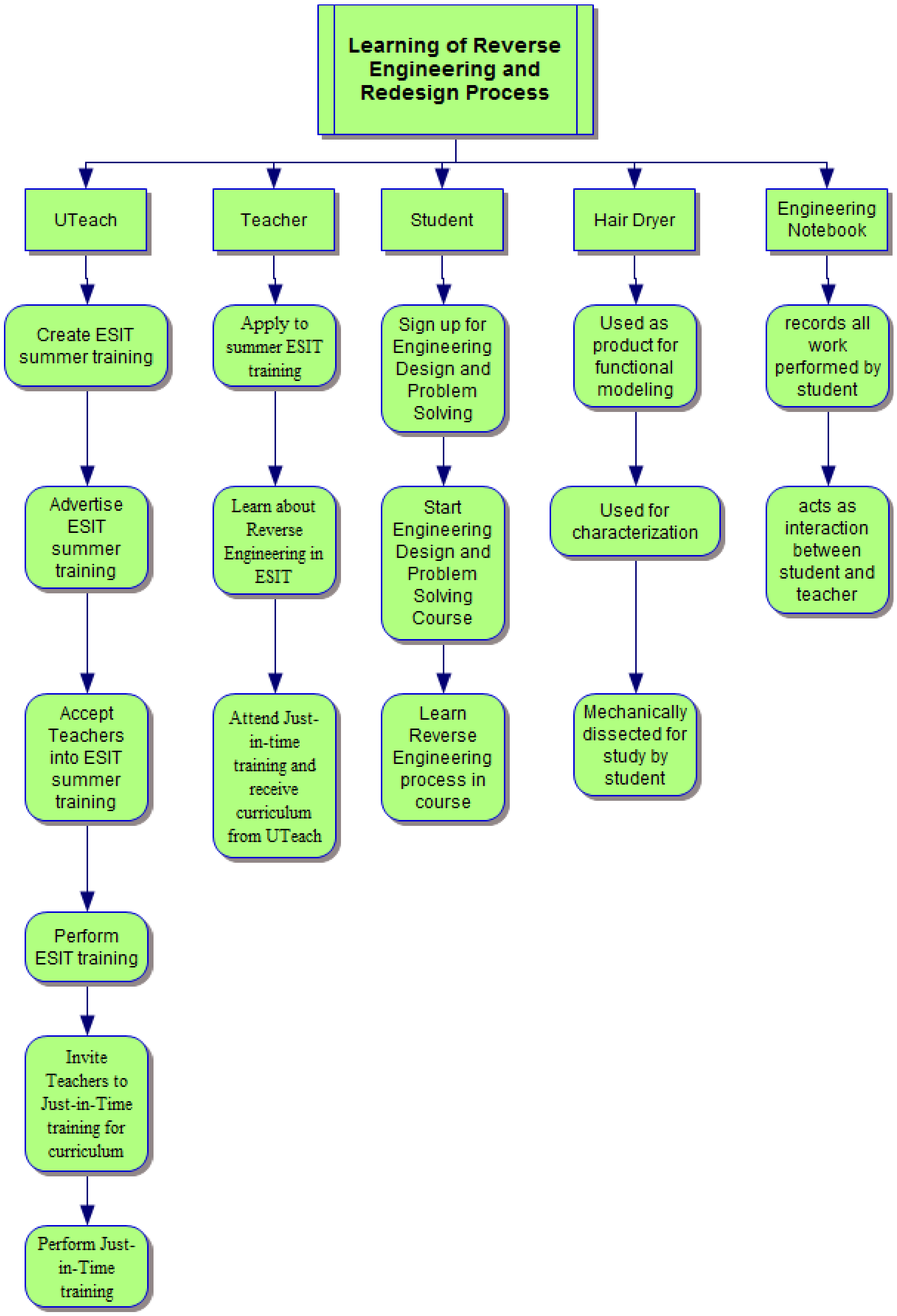

Figure 3: Function Tree of Reverse Engineering Curriculum

Although some of the functions in the function tree are similar, such as UTeach*Engineering* and teachers both participating in the ESIT, the roles of each are very different. UTeach*Engineering* creates the curriculum based on the TEKS and needs of the teachers. In contrast, when the teachers take the training they are not only learning the material, but determining how to best deliver it to his or her students.

Activity Diagram

The activity diagram created for the reverse engineering curriculum is from the perspective of the teachers. Applying to the Engineering Summer Institute for Teachers (ESIT) training is the first step in the path to being able to teach the reverse engineering curriculum. The training does not end at the summer institute; there is also Just-in-time training throughout the year usually offered one or two weeks prior to the start of the reverse engineering unit.

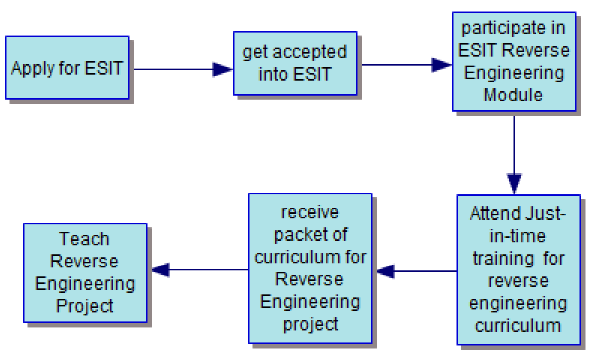

Figure 4: Activity Diagram of Reverse Engineering Curriculum Implementation

Redesigns to the UTeach*Engineering* Reverse Engineering Curriculum

The redesigns of the reverse engineering curriculum include a specification sheet and rubric for every deliverable, addition of a rubric for the engineering notebook, a reflective assignment after the disassembly, a reasoning paragraph about the activity diagram, and hair dryer patent information during the historical timeline task. In the current sequence the concept generation occurred prior to the timeline of innovation. It is important for students to determine the history of the hair dryer and patents associated with the engineering achievements, therefore it is moved to after students create the how it works page.

These redesigns were based off the customer needs analysis and producing curriculum that is easy to implement for teachers. Adding the specification sheet and the rubric allows clear expectations of produced work for the student and for the teacher, provides university based standards for each student deliverable.

Assessments

A question commonly asked by teachers when presented curriculum is: How do I grade that? When work is given to students for which there is one right answer, assessment is straightforward. Rubrics need to be created to assess the process, communicating ideas, and documentation. In a reverse engineering curriculum, one desired outcome is that students learn the process of reverse engineering. “The development of core performance tasks naturally leads to the selection or design of companion scoring rubrics.” (Wiggins and McTighe 2006, 285) Rubrics were created for each of the performance tasks in the UTeach*Engineering* Reverse Engineering curriculum.

In the Engineering the Future curriculum, answers are provided in the teacher manual for questions in the engineering notebook and the text. The final design task is the only part of the project that is assessed using a rubric. The Ford PAS curriculum contains rubrics for the team work activities and the engineering logbook. Currently no rubrics are created for any of the performance tasks in the UTeach*Engineering* reverse engineering curriculum. Rubrics were created for each performance task in the curriculum as part of this redesign activity.

The following sections contain the specification sheets and the rubrics of each deliverable for the reverse engineering and redesign curriculum.

Engineering Notebook Specification Sheet

Engineering notebooks are used throughout various engineering industries as a means to jot down daily information, notes, task lists, quick calculations, sketches and thoughts about future improvements/problems. Engineering notebooks must be bound such that pages cannot be easily removed, and all documentation completed in pen. Some of these notebooks have pre-printed table of contents pages and pre-printed numbers. Good engineers keep their notebook in possession throughout the workday so that daily work can be easily documented. In the high school engineering curriculum, the same requirements are recommended as in engineering industry.

Composition notebooks serve this purpose well because they are bound and are affordable. Regardless of the type of engineering notebook it should contain the following:

- Student name on the front cover
- Title page with name, class, period, school year, and teacher's name (page 1)
- Table of contents with description of work and page number (pages 2-3)
- Page numbers on the front and back of each page

Engineering Notebook

Component	Point Value				
	1	2	3	4	5
Bound Notebook	Notebook is not bound together and papers are difficult to locate		Notebook is bound but in poor condition (ex. pages are torn)		Notebook is bound with all pages intact and in good condition
Neatness	Work presented in engineering notebook is sloppy and extremely difficult to read	Work presented in engineering notebook is sloppy and difficult to read		Work presented in engineering notebook is mostly clear	Work presented in engineering notebook is clear and easy to read
Page Numbers	No pages are numbered	Very few pages are numbered up to latest work location	Most pages numbered up to latest work location	All pages numbered up to latest work location	All pages numbered in entire notebook
Table of Contents	Table of Contents page present but is incomplete and missing page numbers	Table of Contents contains is not up to date some headings and has incomplete page numbers	Table of Contents is mostly up to date but missing a few headings and a few page numbers	Table of Contents is up to date, mostly complete and only missing one or two headings or page numbers	Table of Contents is up to date complete with headings and all page numbers
External Documents	No external documents are fastened in the engineering notebook	Many external documents are not fastened in the engineering notebook and missing titles	Some external documents are not properly fastened in engineering notebook and are missing a title	Most external documents are fastened in engineering notebook on proper day and are properly titled	All external documents are fastened into engineering notebook on proper day completed and include a title
Dated Entries	No Dates before any work and work is not in chronological order	Many dates are missing and work is not in chronological order	Many dates are missing, but work is in chronological order	Very few dates are missing from notebook and work is in chronological order	Dates are placed at the beginning of any new entry and work is in chronological order

Figure 5: Engineering Notebook Guideline Rubrics

Customer Needs Analysis Specification Sheet

Interview a *minimum* of 5 people on the hair dryer. Ask the customers of the hair dryer the following questions and write their responses on the interview worksheet:

- What are your typical uses for a hair dryer?
- What do you like about the model of hair dryer you own?
- What do you dislike about the model of hair dryer you own?
- What is at least one improvement you would like to see on your hair dryer?

After conducting the interviews from the customer statements determine what they mean in engineering terms and write that down in the interpreted need column on the worksheet. Rank each interpreted need from 1 to 5 (5 being the highest) based on your thoughts on the importance of that need to the customer.

Customer Needs Analysis

Component	Point Value				
	1	2	3	4	5
Number of Interviews	Interviews were conducted with 2 people not in EDPS class	Interviews were conducted with 3 people not in EDPS class	Interviews were conducted with 4 people not in EDPS class	Interviews were conducted with 5 people not in EDPS class	Interviews were conducted with more than 5 people not in EDPS class
Interview Worksheet	Interview worksheet was poorly filled out from customer interviews	Interview worksheet was missing several comments in any section	Interview worksheet was only missing 3-4 comments in any section	Interview worksheet was only missing 1-2 comments in any section	Interview worksheet was completely filled out
Interpreted Needs	Interpreted needs contained many dissconnects from customer comments	Interpreted needs contained several errors in identification from customer comments	Interpreted needs contained few errors in identification from customer comments	Interpreted needs only contained minor errors in identification from customer comments	Interpreted needs were correctly identified from customer comments
Determining Importance Interpreted Needs	Importance of interpreted need was not adequately labeled according to view of customer		Importance of interpreted need was adequately labeled with minor errors according to view of customer		Importance of interpreted need was adequately labeled according to view of customer

Figure 6: Customer Needs Analysis Rubric

Characterizing a Hair Dryer Specification Sheet

Use your engineering notebook, lab equipment and the provided tables to determine the following characteristics of the hair dryer:

- Power Input
- Power Output
- Hair Dryer Efficiency
- Drying Time

In your engineering notebook, paste your tables and provide sample calculations for each type of calculation.

Characterizing a Hair Dryer

Component	Point Value				
	1	2	3	4	5
Taking measurements	Student must be directed as to which piece of lab equipment	Student must be directed as to which piece of lab equipment to use most of the time	Student must be directed as to which piece of lab equipment to use 1-2 times	Student knows what piece of lab equipment to use	Student knows what piece of lab equipment to use and is able to assist other students
Recording measurement	Student is missing most of the measurements in data table	Student is missing several measurements in data table	Student is only missing 1-2 measurements in data table	Student completes all measurements in data table	Student completes all measurements in data table with proper significant figures
Accuracy of Calculations	Calculations are inaccurate and contain incorrect significant figures	Calculations and significant figures contain many errors and are mostly incorrect	Calculations are mostly accurate and contain correct significant figures only contain minor erros	Calculations are accurate with minor errors and contain correct significant figures	Calculations are accurate and contain correct significant figures
Sample calculations	No sample calculations are completed	Sample calculations are incomplete and missing units	Sample calculations are missing 1-2 steps and have some incomplete units	Sample calculations are completed but either missing 1-2 steps or units	Sample calculations are completed with all steps and including all units
Safety in the lab	Student is non-compliant of classroom safety procedures	Student has to be reminded 2-3 times of safety procedures	Student must be reminded of lab safety procedures	Student complies with lab safety procedures	Student exceeds all safety requirements and are an example for others
Neatness	Measurements and sample calculations are scribbled and barely legible in data table and notebook	Measurements and sample calculations are not neat in data table and notebook but can be read	Measurements and sample calculations are somewhat neat in data table and notebook but can use improvement	Measurements and sample calculations are mostly neat in data table and notebook	Measurements and sample calculations are written neatly in data table and notebook
Notebook	Student does not place data in notebook	Student is missing data table or sample calculations from notebook	Student has data table and sample calculations in notebook, but not properly placed or labeled on page and table of contents	Student has data table and sample calculations in notebook, but not labeled correctly on page or table of contents	Student has data table and sample calculations in notebook and labeled correctly on page or table of contents

Figure 7: Characterizing a Hair Dryer Rubrics

Memorandum Specification Sheet

Create a memorandum to management about your measurement findings on the hairdryer that was tested. This memo should be 1-2 pages; single spaced, and typed with Arial 12pt font. It shall include a table that summarizes results from the characterization.

Topic: Results of Measuring Characteristics of a Hairdryer

Answer the following questions in paragraph format:

Paragraph 1:

- What are the make and model of the hairdryer that was tested?
- What characteristics (ex. voltage) did you measure on the hairdryer?
- What equipment was used to measure those characteristics?
- Which settings did you test on the hairdryer?
- Which setting on the hairdryer produced the greatest usage efficiency?

Paragraph 2:

- Why was it necessary to measure power input?
- What equation was used determine power input?
- Did the power input change on the hairdryer with the different settings? Why or Why not?

Paragraph 3:

- Why was it necessary to measure power output?
- What equations were used to calculate values to determine power output?
- Which setting on the hairdryer produced the greatest power output value? Why?
- What feature of the hairdryer could be changed to increase the power output?

Paragraph 4:

- What equation was used to calculate the hairdryer efficiency?
- Which setting produced the greatest efficiency?
- What setting had the fastest time to dry?
- How did the hairdryer efficiency relate with time to dry for each setting?

Memorandum

Component	Point Value				
	1	2	3	4	5
Answering Questions	Student does not answer questions posed for the memo	Student only answers one or two of the questions completely and correctly	Memo answers all the questions, but not correctly or concisely	Memo contains minor errors in correctly or concisely answering questions	Memo correctly and concisely answers all questions in each paragraph
Logical Content	Memo provides some information, but not in correct paragraphs which confuses the reader	Student provides some information, but not in correct paragraphs which confuses the reader	Memo contains all relevant information to each question in the correct paragraph allowing reader to understand the topic	Memo contains all relevant information to each question in the correct paragraph allowing reader to understand the topic	Memo contains all relevant information to each question in the correct paragraph allowing reader to understand the topic
Clarity	Memo contains so many errors it distracts from the overall content.	Memo contains several errors in spelling, grammar, and punctuation	Memo contains minor errors in spelling, grammar, and punctuation	Memo contains minor errors in spelling or grammar or punctuation	Memo contains the correct spelling, grammar, and punctuation
Style	Memo contains an abundance of words such as: I, we, and us personalizing the memo	Memo contains many errors in professional language throughout memo, information is not concise and there are many errors in technical writing	Memo contains errors in professional language throughout memo keeping information concise and errors in technical writing	Memo contains minor errors professional language throughout memo keeping information concise and written as a technical document	Memo contains professional language throughout memo keeping information concise and written as a technical document
Format	Memo headings: To, From, Date, RE are incorrect. Typed in a different font or not typed at all, and paragraphs incorrectly formatted	Memo has several formatting errors in the heading and/or typed in incorrect font and missing paragraph formatting	Memo has few formatting errors in the heading and/or typed in incorrect font, single spaced paragraphs with no indentations	Memo is missing one the properly bolded headings: To, From, Date, RE. Typed in Arial 12pt Font, single spaced paragraphs with no indentations	Memo is formatted correctly with properly bolded headings: To, From, Date, RE. Typed in Arial 12pt Font, single spaced paragraphs with no indentations

Figure 8: Memo Rubrics

Black Box Specification Sheet

Create a Black Box model for the hair dryer. In the center of your Black Box place the overall function of the system.

Include input and output flows of the following types:

- Energy
- Material
- Information

Black Box

Component	Point Value				
	1	2	3	4	5
Overall Function	Product is not represented as the overall function of the system		Product is mostly correctly represented as the overall function of the system		Product is correctly represented as the overall function of the system
Energy Labels	Energy inputs and outputs are improperly identified	Only the Energy inputs or outputs are correctly identified	Energy inputs and outputs are mostly correctly identified	Energy inputs and outputs only contain minor errors in identification	Energy inputs and outputs are properly identified
Material Labels	Material inputs and outputs are improperly identified	Only the Material inputs or outputs are correctly identified	Material inputs and outputs are mostly correctly identified	Material inputs and outputs only contain minor errors in identification	Material inputs and outputs are properly identified
Information Labels	Energy inputs and outputs are improperly identified	Only the Energy inputs or outputs are correctly identified	Energy inputs and outputs are mostly correctly identified	Energy inputs and outputs only contain minor errors in identification	Energy inputs and outputs are properly identified
Line Style and Weights	**None of the input and output lines have proper wieght and style**		**1 of the input and output lines have the proper line weight and style**	**2 of the information lines have the proper line weight and style**	**All input and output lines have the proper line weight and style**
Neatness	Work presented in Black Box is sloppy and extremely difficult to read	Work presented in Black Box is sloppy and difficult to read	Work in Black Box is mostly clear	Work presented in Black Box is mostly clear	Work presented in Black Box is clear and easy to read

Figure 9: Black Box Rubrics

Function Tree Specification Sheet

Create a Function Tree for your hair dryer, starting with the energy inputs from your Black Box model. The Function Tree must contain the following:

- Start with the overall function of the system
- Branches must contain the energy inputs from the black box
- Each branch must contain the functions associated with the specific energy flow

Function Tree

Component	Point Value				
	1	2	3	4	5
Start of Function Tree	Function Tree does not begin with the overall function of the system				Function tree begins with the overall function of the system
Branches	Does not have same branches as energy inputs to black box	Function Tree is missing two of the number of branches as the Black Box energy inputs	Function Tree is missing one of the number of branches as the Black Box energy inputs		Function Tree contains the same number of branches as the Black Box energy inputs
Function Vocabulary	each box contains specifics to the product being analyzed	Few of the boxes contain generic terms for function	Most boxes contain generic terms for function	Almost all boxes contain generic terms for function	Each box contains generic terms for function
Arrows	Arrows are not in the correct direction of activities				Arrows are in the correct direction of activities
Neatness	Work presented in Function Tree is sloppy and extremely difficult to read	Work presented in Function Tree is sloppy and difficult to read	Work in Function Tree is mostly clear	Work presented in Function Tree is mostly clear and easy follow	Work presented in Function Tree is clear and easy to follow

Figure 10: Function Tree Rubric

Activity Diagram Specification Sheet

Create an activity diagram of the steps a user would take to use the hair dryer.

The steps need to:

- Be in correct activity sequence
- Have the correct number of activities
- Arrows need to be in the direction of the actions

Activity Diagram

Component	Point Value				
	1	2	3	4	5
Order of Occurance	Activity Diagram is poorly sequenced in order of activity with multiple errors	Activity Diagram is sequenced in order of activity with several errors	Activity Diagram is sequenced in order of activity with some errors	Activity Diagram is sequenced in order of activity with minor errors	Activity Diagram is sequenced in order of activity
Correct number of steps	Activity Diagram contains four errors in the number of steps for product	Activity Diagram contains three errors in the number of steps for product	Activity Diagram contains two errors in the number of steps for product	Activity Diagram contains one error in the number of steps for product	Activity Diagram contains correct number of steps for product
Viewpoint of the user	The Activity Diagram was not created from the perspective of the user		The Activity Diagram was mostly created from the perspective of the user		The Activity Diagram was created from the perspective of the user
Arrows	Arrows are not in the correct direction of activities		Some arrows are in the correct direction of activities		Arrows are in the correct direction of activities
Neatness	Work presented in Activity Diagram is sloppy and extremely difficult to read	Work presented in Activity Diagram is sloppy and difficult to read	Work in Activity Diagram is mostly clear	Work presented in Activity Diagram is mostly clear and easy follow	Work presented in Activity Diagram is clear and easy to follow

Figure 11: Activity Diagram Rubric

Activity Diagram Reasoning Specification Sheet

Write two paragraphs in your engineering notebook about your reasoning behind the activity diagram. Answer the following:

- Why did you choose the steps in the activity diagram?
- Why did you choose to sequence the activities in the order presented?
- How many branches did the activity diagram contain, and why?
- Are there any loops in the activity diagram, why or why not?

Activity Diagram Reasoning Paragraph

Component	Point Value				
	1	2	3	4	5
Answering Questions	Student does not answer questions posed for the Activity Diagram	Student only answers one or two of the questions completely and correctly	Activity Diagram answers all the questions, but not correctly or concisely	Activity Diagram contains minor errors in correctly or concisely answering questions	Activity Diagram correctly and concisely answers all questions in each paragraph
Content	Activity Diagram paragraph does not demonstrate understanding of all activities in sequence for product and is missing key components	Activity Diagram paragraph does not demonstrate understanding of all activities in sequence for product	Activity Diagram paragraph somewhat demonstrates understanding of all activities in sequence for product	Activity Diagram paragraph mostly demonstrates understanding of all activities in sequence for product	Activity Diagram paragraph demonstrates understanding of all activities in sequence for product
Clarity	Activity Diagram contains so many errors it distracts from the overall content.	Activity Diagram contains several errors in spelling, grammar, and punctuation	Activity Diagram contains minor errors in spelling, grammar, and punctuation	Activity Diagram contains minor errors in spelling or grammar or punctuation	Activity Diagram contains the correct spelling, grammar, and punctuation
Style	Activity Diagram contains an abundance of words such as: I, we, and us personalizing the Activity Diagram	Activity Diagram contains many errors in professional language throughout Activity Diagram, information is not concise and there are many errors in technical writing	Activity Diagram contains errors in professional language throughout Activity Diagram keeping information concise and errors in technical writing	Activity Diagram contains minor errors professional language throughout Activity Diagram keeping information concise and written as a technical document	Activity Diagram contains professional language throughout Activity Diagram keeping information concise and written as a technical document

Figure 12: Activity Diagram Reasoning Paragraph

Disassembly Specification Sheet

As you disassemble the hair dryer the following need to be addressed:

- Make observations before disassembly of each component.
- Identify major components.
- Throughout the disassembly process document EVERY step and part that is removed.
- Take pictures or make sketches of each major component disassembly.
- Keep track of all parts (screws, nuts, etc.).

Disassembly

Component	Point Value				
	1	2	3	4	5
Safety	Student is non-compliant of classroom safety procedures	Student has to be reminded 2-3 times of safety procedures	Student must be reminded of lab safety procedures	Student complies with lab safety procedures	Student exceeds all safety requirements and are an example for others
Proper Use of Tools	Student must be directed as to which tools to use	Student must be directed as to which tools to use most of the time	Student must be directed as to which tools to use 1-2 times	Student knows what tools to use	Student knows what tools to use and is able to assist other students
Lab Space Organization	Student's space is disorganized and not picked up before the end of class				Student's space is fully cleaned up with tools and equipment put properly away
Drawings/Diagrams/Pictures	Student is missing drawings/diagrams or pictures for each disassembly step placed in notebook with labels	Student is missing most drawings/diagrams or pictures for each disassembly step placed in notebook with labels	Student has some drawings/diagrams or pictures for each disassembly step placed in notebook with labels	Student is missing one drawings/diagrams or pictures for each disassembly step placed in notebook with labels	Student has drawings/diagrams or pictures for each disassembly step placed in notebook with labels
Participation	Students does not participate in Disassembly Procedures		Student participates in Disassembly Procedures with several redirections		Students fully participates in Disassembly Procedures
Notebook	Student does not place disassembly in notebook	Student is missing disassembly notes from notebook	Student has disassembly notes, but not properly placed or labeled on page and table of contents	Student has disassembly notes in notebook, but not labeled correctly on page or table of contents	Student has disassembly notes in notebook and labeled correctly on page or table of contents

Figure 13: Disassembly Rubric

Disassembly Reflection Specification Sheet

Write a one page reflection in your engineering notebook about findings during the disassembly process.

The page should include:

- Tools that are needed that were not present.
- Components that were expected based on functional models.
- Components that were not expected based on functional models.
- Information that should be researched for a better understanding of the inner workings of the hair dryer.

Disassembly Reflection

Component	Point Value				
	1	2	3	4	5
Inner workings of hair dryer	No components were listed that were expected or not expected based on functional modeling with no explanation		Some components that were expected and not expected are listed based on functional modeling with minimal explanation		Components that were expected and not expected are listed based on functional modeling with adequate explanation
Information to be Researched for future learning	Reflection contains no identification of engineering concepts needed to be researched for further understanding of how the hair dryer works	Reflection contains improper identification of engineering concepts needed to be researched for further understanding of how the hair dryer works	Reflection contains mostly proper identification of engineering concepts needed to be researched for further understanding of how the hair dryer works	Reflection contains minor errors in identification of engineering concepts needed to be researched for further understanding of how the hair dryer works	Reflection contains proper identification of engineering concepts needed to be researched for further understanding of how the hair dryer works
Clarity	Reflection contains so many errors it distracts from the overall content.	Reflection contains several errors in spelling, grammar, and punctuation throughout the memo	Reflection contains minor errors in spelling, grammar, and punctuation throughout the memo	Reflection contains minor errors in spelling or grammar or punctuation throughout the memo	Reflection contains the correct spelling, grammar, and punctuation throughout the memo
Length	Reflection is only a couple of sentences in length		Reflection is one paragraph in length		Reflection is one page in length
Organization	Reflection is poorly organized and that it is difficult for the reader to follow the main point	Reflection is poorly organized so that it is somewhat difficult for the reader to follow the main point	Reflection is mostly organized so that it is not to difficult for the reader to follow the main point	Reflection is organized so that it is not too difficult for the reader to follow the main point	Reflection is well organized so that it is easy for the reader to follow the main point

Figure 14: Disassembly Reflection Rubric

Assembly Procedures Specification Sheet

Write assembly procedures in order of assembly so that someone can put your hairdryer model back together. The instructions should be clear and concise so that they are easy to follow. In the instructions you should include:

- Pictures with labels for each assembly step.
- Tools required for each step.

Assembly Procedures

Component	Point Value				
	1	2	3	4	5
Order of Assembly	Directions are not in order and missing several steps	Many directions are out of assembly order and steps are missing	Some directions may be out of assembly order or missing	Directions are in order for assembly but one or two steps are missing	All steps are present and in proper order of assembly
Clarity	Directions are not clear and confusing to follow. Terminology is commonly misused	Directions are somewhat confusing and some terminology is correct	Directions are somewhat easy to follow and most terminology is correct	Minor confusions are made in directions but they are easy to follow and proper terminology is used	Directions are easy to follow and proper terminology is used
Pictures	No pictures are used in assembly procedures	Pictures are present but not clear and missing several labels	Pictures are present and clear but labeling is inconsistent	Pictures are clear but some labels are missing or inconsistent	Pictures are clear labeled and present in every step
Tools Required	No required tools are listed on assembly procedures	Very few required tools are listed in assembly procedures. Many steps are missing required tools	Most required tools are listed in assembly procedures but some steps are missing tools	Required tools are listed out in every step, but some may be incorrect	Required tools are listed in every step of the assembly procedures

Figure 15: Assembly Procedures Rubric

Timeline of Innovation Specification Sheet

Create a timeline of innovation for the hair dryer device. Identify the steps in the timeline of the development of the hair dryer of major advances in technology. Include the following information:

- "When is the first record of the hair dryer design? Who used it?" (UT curriculum 2010)
- In what years did the major changes occur in the hair dryer?
- "How much power do modern hair dryers produce compared to early hand-held hair dryers" (UT curriculum 2010)

Pick one of the major advances in the hair dryer and write two paragraphs about the advancement. Answer the following questions in your paragraph:

- What was the advancement made in the hair dryer?
- In what decade did this advancement occur?
- Were there any historical significant technological changes during that time? How did they affect the advancement?
- Was the advancement a parametric, adaptive, or original redesign of the hair dryer? Why?

Timeline of Innovation

Component	Point Value				
	1	2	3	4	5
Advancements in Technology	Only 1 advancements were identified in the development in the hair dryer	Two advancements were identified in the development in the hair dryer	Three advancements were identified in the development in the hair dryer	Four advancements were identified in the development in the hair dryer	At least 5 advancements were identified in the development in the hair dryer
Neatness	Work presented in Timeline of Innovation is sloppy and extremely difficult to read	Work presented in Timeline of Innovation is sloppy and difficult to read	Work in Timeline of Innovation is mostly clear	Work presented in Timeline of Innovation is mostly clear and easy follow	Work presented in Timeline of Innovation is clear and easy to follow
Answering Questions	Student does not answer questions posed for the Advancement	Student only answers one or two of the questions completely and correctly	Advancement answers all the questions, but not correctly or concisely	Advancement contains minor errors in correctly or concisely answering questions	Advancement correctly and concisely answers all questions in each paragraph
Logical Content	Advancement provides some information, but not in correct paragraphs which confuses the reader	Student provides some information, but not in correct paragraphs which confuses the reader	Advancement contains all relevant information to each question in the correct paragraph allowing reader to understand the topic	Advancement contains all relevant information to each question in the correct paragraph allowing reader to understand the topic	Advancement contains all relevant information to each question in the correct paragraph allowing reader to understand the topic
Clarity	Advancement contains so many errors it distracts from the overall content.	Advancement contains several errors in spelling, grammar, and punctuation	Advancement contains minor errors in spelling, grammar, and punctuation	Advancement contains minor errors in spelling or grammar or punctuation	Advancement contains the correct spelling, grammar, and punctuation
Style	Advancement contains an abundance of words such as: I, we, and us personalizing the Advancement	Advancement contains many errors in professional language throughout Advancement, information is not concise and there are many errors in technical writing	Advancement contains errors in professional language throughout Advancement keeping information concise and errors in technical writing	Advancement contains minor errors professional language throughout Advancement keeping information concise and written as a technical document	Advancement contains professional language throughout Advancement keeping information concise and written as a technical document

Figure 16: Timeline of Innovation Rubric

How it Works Page Specification Sheet

Create a two page explanation of how the hair dryer works similar to a page that is found in David Macaulay's book *The Way Things Work*.

The pages should contain a paragraph definition of the hair dryer which covers the main function, a brief history, and a quick description of how the hair dryer works.

Other descriptive statements (2-3 sentences) with a visual should include:

- Inputs to the hair dryer
- Outputs to the hair dryer
- Variations in human control
- Direction of air flow in the hair dryer
- Direction of electricity flow in the hair dryer
- Sketch and Label the main components in the hair dryer
    - Switch(s)
    - Hand grip
    - Heating element
    - Nozzle
    - Fan
    - Cord
    - Motor
    - Attachments

How it Works Page

Component	Point Value				
	1	2	3	4	5
Content	Pages are missing most of the required content from the specification sheet	Pages contain few of the required content from the specification sheet	Pages contain most of the required content from the specification sheet	Pages contain almost all of the required content from the specification sheet	Pages contain all the required content from the specification sheet
Clarity	Pages contain so many errors it distracts from the overall content.	Pages contain several errors in spelling, grammar, and punctuation throughout the memo	Pages contain minor errors in spelling, grammar, and punctuation throughout the memo	Pages contain minor errors in spelling or grammar or punctuation throughout the memo	Pages contain the correct spelling, grammar, and punctuation throughout the memo
Accuracy	Most information presented on the page is not scientifically correct		Most Information presented on the page is scientifically correct		Information presented on the page is scientifically correct
Graphics	Diagrams and sketches of the hairdryer are not detailed, labeled or colorful	Diagrams and sketches of the hairdryer are somewhat detailed, labeled and colorful	Diagrams and sketches of the hairdryer are mostly detailed, labeled and colorful	Diagrams and sketches of the hairdryer are almost all detailed, labeled and colorful	Diagrams and sketches of the hairdryer are detailed, labeled and colorful
Organization	Page layout is not appealing to the reader. Drawings and descriptions are not organized and easy to follow	Page layout is somewhat appealing to the reader. Drawings and descriptions are somewhat organized and easy to follow	Page layout is mostly appealing to the reader. Drawings and descriptions are mostly organized and easy to follow	Page layout is appealing to the reader. Drawings and descriptions are mostly organized and easy to follow	Page layout is appealing to the reader. Drawings and descriptions are organized and easy to follow

Figure 17: How it Works Page Rubrics

Patent Research Specification Sheet

Go to http://www.google.com/patents and search for patents on the hair dryer. In your engineering notebook, record notes on the 3 different patents with different types of improvements that were patented for the hair dryer. Place the following in your engineering notebook:

- Patent Number
- Inventor
- Sketch the design
- For each patent: write one paragraph explaining the patented design and answering the following:
    - What is the purpose of the design?
    - Has this design been produced?

Patent Search

Component	Point Value				
	1	2	3	4	5
Patents in Technology	One patent was researched with notes recorded in the engineering notebook		Two patents were researched with notes recorded in the engineering notebook		Three patents were researched with notes recorded in the engineering notebook
Answering Questions	Student does not answer questions posed for the patent research	Student only answers one or two of the patent research paragraph questions completely and correctly	Patent research paragraph answers all the questions, but not correctly or concisely	Patent research paragraph contains minor errors in correctly or concisely answering questions	Patent research paragraph correctly and concisely answers all questions in each paragraph
Logical Content	Patent provides some information, but not in correct paragraphs which confuses the reader	Student provides some information, but not in correct paragraphs which confuses the reader	Patent research contains all relevant information to each question in the correct paragraph allowing reader to understand the topic	Patent research contains all relevant information to each question in the correct paragraph allowing reader to understand the topic	Patent research contains all relevant information to each question in the correct paragraph allowing reader to understand the topic
Clarity	Patent research paragraphs contains so many errors it distracts from the overall content.	Patent research paragraphs contains several errors in spelling, grammar, and punctuation	Patent research paragraphs contains minor errors in spelling, grammar, and punctuation	Patent research paragraphs contains minor errors in spelling or grammar or punctuation	Patent research paragraphs contains the correct spelling, grammar, and punctuation
Style	Patent research paragraph contains an abundance of words such as: I, we, and us personalizing the Patent	Patent research paragraph contains many errors in professional language throughout Patent, information is not concise and there are many errors in technical writing	Patent research paragraph contains errors in professional language throughout Patent keeping information concise and errors in technical writing	Patent research paragraph contains minor errors professional language throughout Patent keeping information concise and written as a technical document	Patent research paragraph contains professional language throughout Patent keeping information concise and written as a technical document

Figure 18: Patent Search Rubric

Concept Generation Specification Sheet

MIND MAP

Create a mind map of ideas for redesigning a hairdryer. In the center begin with the focus of the hair dryer and create branches to determine ways to make that happen. From those branches, problem solutions could be added. Come up with as many ideas as possible to find solutions that will solve the same goal as the hair dryer.

6-3-5

In your teams, brainstorm ideas using the 6-3-5 concept generation. The following should be completed:

- "Each team member has a large sheet of paper and a different colored pencil
- Each team member sketches 3 detailed items
- Pass papers to the right
- Next team member modifies by adding, without erasing, new ideas
- Keep passing until you get your own paper back" (UTeach curriculum 2010)

Concept Generation

Component	Point Value				
	1	2	3	4	5
Mind Mapping	Mind map has at least 1 branches from the goal of the system and/or less than and 3 ideas attached to each branch	Mind map has at least 1 branches from the goal of the system and/or less than 3 ideas attached to each branch	Mind map has at least 2 branches from the goal of the system and 3 ideas attached to each branch	Mind map has at least 3 branches from the goal of the system and 3 ideas attached to each branch	Mind map has at least 4 branches from the goal of the system and 3 ideas attached to each branch
6-3-5	6-3-5 concept generation only contains two drawings in the first process but the additions of ideas are minimal	6-3-5 concept generation only contains two drawings in the first process and additions of ideas are mostly completed on each paper during paper passing	6-3-5 concept generation is completed in the initial idea step of the process but the additions of ideas are minimal	6-3-5 concept generation is completed in the initial idea step of the process and additions of ideas are mostly completed on each paper during paper passing	6-3-5 concept generation is completed in each step of the process initial creation and addition of ideas as paper passing occurs

Figure 19: Concept Generation Rubrics

Pugh Chart Specification Sheet

As a team, pick six of the concepts your team came up with during the concept generation task. Create a Pugh Chart for those concepts and include the specifications from customer needs analysis and specification procedures completed earlier in this project. Use the following methodology to fill out the Pugh Chart worksheet:

1. “Choose decision criteria
    a. 5-10
    b. Quantifiable
    c. Differentiate the concepts
2. Make a matrix with concepts in columns and criteria in rows.
3. Choose a reference concept
    a. Existing product
    b. Competitor to beat
    c. Easiest to implement
    d. Team consensus
4. For each concept, rate its performance, compared to the reference concept, with respect to each criterion
    a. Quantitative basis
    b. Enter -1 for worse than, 0 for same as, 1 for better than
5. Total -1’s and +1’s for each concept and compare
6. Attack the negatives

a. Analyze the negatives of each concept and try to improve

b. Combine concepts with complementary strengths and weaknesses" (UTeach curriculum, 2010)

Pugh Chart

Component	Point Value				
	1	2	3	4	5
Concept selection	Students select 2-3 concepts from their concept generation to place in the pugh comparison worksheet		Students select 4-5 concepts from their concept generation to place in the pugh comparison worksheet		Students select 6 concepts from their concept generation to place in the pugh comparison worksheet
Pugh Chart Worksheet	Pugh chart worksheet was minimally filled out and no optimum design alternative was chosen	Pugh chart worksheet was minimum filled out and optimum design alternative was chosen	Pugh chart worksheet was mostly filled out and no optimum design alternative was chosen	Pugh chart worksheet was mostly filled out and optimum design alternative was chosen	Pugh chart worksheet was completely filled out and optimum design alternative was chosen
Determining specification weight	Specification weight was not adequately labeled on Pugh Chart worksheet according to view of customer for each concept	Specification weight was somewhat labeled on Pugh Chart worksheet according to view of customer for each concept		Specification weight was mostly labeled on Pugh Chart worksheet according to view of customer for each concept	Specification weight was adequately labeled on Pugh Chart worksheet according to view of customer for each concept

Figure 20: Pugh Chart Rubric

Presentation Specification Sheet

Create a presentation of the reverse engineering and redesign process you completed for the hair dryer. Answer the following in your presentation:

- What hair dryer model did you evaluate?
- What were the results from testing?
- What happened in the disassembly process?
- What were some of the concepts from generating ideas?
- What are the results of the Pugh Chart?
- Show a sketch of the new concept from the Pugh Chart.
- What did you learn from the reverse engineering and redesign process?

Presentation

Component	Point Value				
	1	2	3	4	5
Content					
Content Knowledge	Student was not able to recall presentation content	Student had mastery of presentation content and was able to answer questions without referring to presentation slides or other team members for answers	Student had mastery of presentation content and was able to answer questions without referring to presentation slides or other team members for answers	Student mostly had mastery of presentation content and was able to answer questions with minimal referral to presentation slides or other team members for answers	Student had mastery of presentation content and was able to answer questions without referring to presentation slides or other team members for answers
Delivery			Student had some difficulty presenting in a clear voice and tone that was engaging to the audience	Student mostly delivered presentation in a clear voice and tone that was engaging to the audience	Student delivered presentation in a clear voice and tone that was engaging to the audience
Time	Presentation was less than 2 minutes	Presentation was 2-5 minutes in length	Presentation was 6-7 minutes in length	Presentation was 7-8 minutes in length	Presentation was 8-10 minutes in length
Visuals	Presentation did not contain any visuals		Presentation did not contain adequate amount of visuals to enhance the content		Presentation contained visuals that enhanced the content
Clarity	Presentation contains so many errors it distracts from the overall content.	Presentation contains several errors in spelling and grammar	Presentation contains minor errors in spelling and grammar	Presentation contains minor errors in spelling or grammar	Presentation contains the correct spelling, grammar
Organization	Presentation provides some information, but in a confusing manner	Presentation contains some information required from specification sheet, but organized in a confusing manner	Presentation somewhat contains all relevant information to each question in the specification sheet but organized in a confusing manner	Presentation mostly contains all relevant information to each question in the specification sheet and organized in a manner that makes sense to the audience	Presentation contains all relevant information to each question in the specification sheet and organized in a manner that makes sense to the audience

Figure 21: Presentation Rubric

Project Reflection Specification Sheet

Write a reflection of the Reverse Engineering and Redesign project in your engineering notebook. The reflection should be approximately two pages, written in essay form and answer all questions below.

- Which steps in the Engineering Design Cycle did you use during the Reverse Engineering and Redesign project?
- How does watching other teams' presentations influence your concept development? Would you make any changes to your concept? Why or why not?
- How would you assess your performance during the project?
    - Did you participate in all activities?
    - Did all your team members participate in all activities? If not, what could you have done to help him/her get involved?
- What part of the project did you enjoy the best?
- What part of the project do you think needs improvement? (You must pick one) and what would you do to improve that activity?
- If you could reverse engineer and redesign any device, what would you choose? Why? (remember it has to be something that has to have measureable characteristics)

Project Reflection

Component	Point Value				
	1	2	3	4	5
Suggestions for improvement	No suggestions for improvement are mentioned in reflection		One suggestion for improvement is mentioned in reflection		Two suggestions for improvement are mentioned in reflection
Items for future reverse engineering	No item is suggested to reverse engineer.	Only one item is suggested to reverse engineer. Item does not contain a description of characteristics that can be measured.	Only one item is suggested to reverse engineer. Item contains a description of characteristics that can be measured.	Two or more items are suggested to reverse engineer. Only one item contains a description of characteristics that can be measured.	Two or more items are suggested to reverse engineer. Each item contains a description of characteristics that can be measured.
Clarity	Reflection contains so many errors it distracts from the overall content.	Reflection contains several errors in spelling, grammar, and punctuation throughout the memo	Reflection contains minor errors in spelling, grammar, and punctuation throughout the memo	Reflection contains minor errors in spelling or grammar or punctuation throughout the memo	Reflection contains the correct spelling, grammar, and punctuation throughout the memo
Length	Reflection is only a couple of sentences in length		Reflection is one paragraph in length		Reflection is two or more paragraphs in length
Organization	Reflection is poorly organized and that it is difficult for the reader to follow the main point	Reflection is poorly organized so that it is somewhat difficult for the reader to follow the main point	Reflection is mostly organized so that it is not to difficult for the reader to follow the main point	Reflection is organized so that it is not too difficult for the reader to follow the main point	Reflection is well organized so that it is easy for the reader to follow the main point

Figure 22: Project Reflection Rubrics

Chapter 6: Conclusions and Future Work

The reverse engineering and redesign process was applied to the UTeach*Engineering* Reverse Engineering curriculum. An analysis was conducted of the FORD PAS, Engineering the Future and UTeach reverse engineering curriculums to determine which TEKS were covered. After the analysis, additions of writing components within the curriculum and rubrics were created for each of the student deliverables from the UTeach*Engineering* Reverse Engineering Curriculum. After the additions, the curriculum is more robust as the rubrics can be used for the reverse engineering of any product. It also includes more opportunities for student reflection of the process.

For future additions, curricula should be created for a variety of items the can be reverse engineered. Also, repetition of the reverse engineering process is important for students to understand the process. After students complete the hair dryer project they could reverse engineer a smaller item such as a toy on their own using their new knowledge of the process. A book discussing the reverse engineering and redesign process to supplement the material in the curriculum would also be an additional bonus for student understanding of the reverse engineering and redesign process.

Appendix A: Engineering the Future Reverse Engineering TEKS by Task

Task 3.1

3(B) read and comprehend technical documents, including specifications and procedures

4(F) describe the importance of patents and the protection of intellectual property rights

6(I) maintain an engineering notebook that chronicles work such as ideas, concepts, inventions, sketches, and experiments

Task 3.2

1(A) demonstrate safe practices during engineering field and laboratory activities; and

6(C) work in teams and share responsibilities, acknowledging, encouraging, and valuing contributions of all team members

6(I) maintain an engineering notebook that chronicles work such as ideas, concepts, inventions, sketches, and experiments

Task 3.3

2(A) apply scientific processes and concepts outlined in the Texas Essential Knowledge and Skills (TEKS) for Biology, Chemistry, or Physics relevant to engineering design problems;

2(B) apply concepts, procedures, and functions outlined in the TEKS for Algebra I, Geometry, and Algebra II relevant to engineering design problems

2(H) describe the difference between open-loop and closed-loop control systems

6(C) work in teams and share responsibilities, acknowledging, encouraging, and valuing contributions of all team members

6(I) maintain an engineering notebook that chronicles work such as ideas, concepts, inventions, sketches, and experiments

Task 3.4

2(A) apply scientific processes and concepts outlined in the Texas Essential Knowledge and Skills (TEKS) for Biology, Chemistry, or Physics relevant to engineering design problems

2(B) apply concepts, procedures, and functions outlined in the TEKS for Algebra I, Geometry, and Algebra II relevant to engineering design problems

2(G) identify the inputs, processes, outputs, control, and feedback associated with open and closed systems

6(C) work in teams and share responsibilities, acknowledging, encouraging, and valuing contributions of all team members

6(I) maintain an engineering notebook that chronicles work such as ideas, concepts, inventions, sketches, and experiments

Task 3.5

2(A) apply scientific processes and concepts outlined in the Texas Essential Knowledge and Skills (TEKS) for Biology, Chemistry, or Physics relevant to engineering design problems

2(B) apply concepts, procedures, and functions outlined in the TEKS for Algebra I, Geometry, and Algebra II relevant to engineering design problems

2(C) select appropriate mathematical models to develop solutions to engineering design problems

3(D) organize information for visual display and analysis using appropriate formats for various audiences, including, but not limited to, graphs and tables

6(C) work in teams and share responsibilities, acknowledging, encouraging, and valuing contributions of all team members

6(I) maintain an engineering notebook that chronicles work such as ideas, concepts, inventions, sketches, and experiments

Task 3.6

1(A) demonstrate safe practices during engineering field and laboratory activities; and

2(A) apply scientific processes and concepts outlined in the Texas Essential Knowledge and Skills (TEKS) for Biology, Chemistry, or Physics relevant to engineering design problems

2(G) identify the inputs, processes, outputs, control, and feedback associated with open and closed systems

3(D) organize information for visual display and analysis using appropriate formats for various audiences, including, but not limited to, graphs and tables

6(C) work in teams and share responsibilities, acknowledging, encouraging, and valuing contributions of all team members

6(I) maintain an engineering notebook that chronicles work such as ideas, concepts, inventions, sketches, and experiments

Task 3.7

1(A) demonstrate safe practices during engineering field and laboratory activities; and

2(A) apply scientific processes and concepts outlined in the Texas Essential Knowledge and Skills (TEKS) for Biology, Chemistry, or Physics relevant to engineering design problems

2(B) apply concepts, procedures, and functions outlined in the TEKS for Algebra I, Geometry, and Algebra II relevant to engineering design problems

6(C) work in teams and share responsibilities, acknowledging, encouraging, and valuing contributions of all team members

6(I) maintain an engineering notebook that chronicles work such as ideas, concepts, inventions, sketches, and experiments

Task 3.8

1(A) demonstrate safe practices during engineering field and laboratory activities; and

2(A) apply scientific processes and concepts outlined in the Texas Essential Knowledge and Skills (TEKS) for Biology, Chemistry, or Physics relevant to engineering design problems

3(D) organize information for visual display and analysis using appropriate formats for various audiences, including, but not limited to, graphs and tables

6(C) work in teams and share responsibilities, acknowledging, encouraging, and valuing contributions of all team members

6(I) maintain an engineering notebook that chronicles work such as ideas, concepts, inventions, sketches, and experiments

Appendix B: Ford PAS Reverse Engineering TEKS by Activity

Activity 1

2(F) investigate and apply relevant chemical, mechanical, biological, electrical, and physical properties of materials to engineering design problems;

3(C) prepare written documents such as memorandums, emails, design proposals, procedural directions, letters, and technical reports using the formatting and terminology conventions of technical documentation;

4(A) identify and describe career options, working conditions, earnings, and educational requirements of various engineering disciplines such as those listed by the Texas Board of Professional Engineers;

4(D) describe how technology has evolved in the field of engineering and consider how it will continue to be a useful tool in solving engineering problems;

5(D) establish and evaluate constraints pertaining to a problem, including, but not limited to, health, safety, social, environmental, ethical, political, regulatory, and legal;

6(C) work in teams and share responsibilities, acknowledging, encouraging, and valuing contributions of all team members

6(D) compare and contrast the roles of a team leader and other team responsibilities

6(I) maintain an engineering notebook that chronicles work such as ideas, concepts, inventions, sketches, and experiments

Activity 2

2(F) investigate and apply relevant chemical, mechanical, biological, electrical, and physical properties of materials to engineering design problems

3(A) communicate visually by sketching and creating technical drawings using established engineering graphic tools, techniques, and standards

3(B) read and comprehend technical documents, including specifications and procedures

3(C) prepare written documents such as memorandums, emails, design proposals, procedural directions, letters, and technical reports using the formatting and terminology conventions of technical documentation

4(A) identify and describe career options, working conditions, earnings, and educational requirements of various engineering disciplines such as those listed by the Texas Board of Professional Engineers

5(E) identify or create alternative solutions to a problem using a variety of techniques such as brainstorming, reverse engineering, and researching engineered and natural solutions

6(C) work in teams and share responsibilities, acknowledging, encouraging, and valuing contributions of all team members

6(I) maintain an engineering notebook that chronicles work such as ideas, concepts, inventions, sketches, and experiments

Activity 3

1(B) make informed choices in the use and conservation of resources, recycling of materials, and the safe and legal disposal of materials

2(F) investigate and apply relevant chemical, mechanical, biological, electrical, and physical properties of materials to engineering design problems

3(A) communicate visually by sketching and creating technical drawings using established engineering graphic tools, techniques, and standards

3(F) defend a design solution in a presentation

4(D) describe how technology has evolved in the field of engineering and consider how it will continue to be a useful tool in solving engineering problems;

4(E) discuss the history and importance of engineering innovation on the United States economy and quality of life

5(E) identify or create alternative solutions to a problem using a variety of techniques such as brainstorming, reverse engineering, and researching engineered and natural solutions

6(C) work in teams and share responsibilities, acknowledging, encouraging, and valuing contributions of all team members

6(I) maintain an engineering notebook that chronicles work such as ideas, concepts, inventions, sketches, and experiments

Activity 4

3(A) communicate visually by sketching and creating technical drawings using established engineering graphic tools, techniques, and standards

3(B) read and comprehend technical documents, including specifications and procedures

3(C) prepare written documents such as memorandums, emails, design proposals, procedural directions, letters, and technical reports using the formatting and terminology conventions of technical documentation

5(E) identify or create alternative solutions to a problem using a variety of techniques such as brainstorming, reverse engineering, and researching engineered and natural solutions

6(C) work in teams and share responsibilities, acknowledging, encouraging, and valuing contributions of all team members

6(I) maintain an engineering notebook that chronicles work such as ideas, concepts, inventions, sketches, and experiments

Activity 5

2(A) apply scientific processes and concepts outlined in the Texas Essential Knowledge and Skills (TEKS) for Biology, Chemistry, or Physics relevant to engineering design problems

2(F) investigate and apply relevant chemical, mechanical, biological, electrical, and physical properties of materials to engineering design problems

3(B) read and comprehend technical documents, including specifications and procedures

5(F) test and evaluate proposed solutions using methods such as models, prototypes, mock-ups, simulations, critical design review, statistical analysis, or experiments

6(C) work in teams and share responsibilities, acknowledging, encouraging, and valuing contributions of all team members

6(I) maintain an engineering notebook that chronicles work such as ideas, concepts, inventions, sketches, and experiments

Activity 6

3(C) prepare written documents such as memorandums, emails, design proposals, procedural directions, letters, and technical reports using the formatting and terminology conventions of technical documentation

4(B) recognize that engineers are guided by established codes emphasizing high ethical standards

6(A) participate in the design and implementation of a real or simulated engineering project

Appendix C: UTeach*Engineering* Reverse Engineering Curriculum TEKS by Day

Day 1

6(A) participate in the design and implementation of a real or simulated engineering project

6(H) analyze and critique the results of an engineering design project

6(I) maintain an engineering notebook that chronicles work such as ideas, concepts, inventions, sketches, and experiments

Day 2

3(D) organize information for visual display and analysis using appropriate formats for various audiences, including, but not limited to, graphs and tables

5(E) identify or create alternative solutions to a problem using a variety of techniques such as brainstorming, reverse engineering, and researching engineered and natural solutions

6(A) participate in the design and implementation of a real or simulated engineering project

6(C) work in teams and share responsibilities, acknowledging, encouraging, and valuing contributions of all team members

6(I) maintain an engineering notebook that chronicles work such as ideas, concepts, inventions, sketches, and experiments

Day 3

3(D) organize information for visual display and analysis using appropriate formats for various audiences, including, but not limited to, graphs and tables

6(C) work in teams and share responsibilities, acknowledging, encouraging, and valuing contributions of all team members

6(I) maintain an engineering notebook that chronicles work such as ideas, concepts, inventions, sketches, and experiments

Day 4

1(A) demonstrate safe practices during engineering field and laboratory activities

2(A) apply scientific processes and concepts outlined in the Texas Essential Knowledge and Skills (TEKS) for Biology, Chemistry, or Physics relevant to engineering design problems

2(B) apply concepts, procedures, and functions outlined in the TEKS for Algebra I, Geometry, and Algebra II relevant to engineering design problems

2(C) select appropriate mathematical models to develop solutions to engineering design problems

2(I) make measurements and specify tolerances with minimum necessary accuracy and precision

2(J) use appropriate measurement systems, including customary and International System (SI) of units

6(C) work in teams and share responsibilities, acknowledging, encouraging, and valuing contributions of all team members

6(I) maintain an engineering notebook that chronicles work such as ideas, concepts, inventions, sketches, and experiments

Day 5

1(A) demonstrate safe practices during engineering field and laboratory activities

2(A) apply scientific processes and concepts outlined in the Texas Essential Knowledge and Skills (TEKS) for Biology, Chemistry, or Physics relevant to engineering design problems

2(B) apply concepts, procedures, and functions outlined in the TEKS for Algebra I, Geometry, and Algebra II relevant to engineering design problems

2(C) select appropriate mathematical models to develop solutions to engineering design problems

2(I) make measurements and specify tolerances with minimum necessary accuracy and precision

2(J) use appropriate measurement systems, including customary and International System (SI) of units

6(C) work in teams and share responsibilities, acknowledging, encouraging, and valuing contributions of all team members

6(I) maintain an engineering notebook that chronicles work such as ideas, concepts, inventions, sketches, and experiments

Day 6

1(A) demonstrate safe practices during engineering field and laboratory activities

2(A) apply scientific processes and concepts outlined in the Texas Essential Knowledge and Skills (TEKS) for Biology, Chemistry, or Physics relevant to engineering design problems

2(B) apply concepts, procedures, and functions outlined in the TEKS for Algebra I, Geometry, and Algebra II relevant to engineering design problems

2(C) select appropriate mathematical models to develop solutions to engineering design problems

2(I) make measurements and specify tolerances with minimum necessary accuracy and precision

2(J) use appropriate measurement systems, including customary and International System (SI) of units

6(C) work in teams and share responsibilities, acknowledging, encouraging, and valuing contributions of all team members

6(I) maintain an engineering notebook that chronicles work such as ideas, concepts, inventions, sketches, and experiments

Day 7

1(A) demonstrate safe practices during engineering field and laboratory activities

2(A) apply scientific processes and concepts outlined in the Texas Essential Knowledge and Skills (TEKS) for Biology, Chemistry, or Physics relevant to engineering design problems

2(B) apply concepts, procedures, and functions outlined in the TEKS for Algebra I, Geometry, and Algebra II relevant to engineering design problems

2(C) select appropriate mathematical models to develop solutions to engineering design problems

2(I) make measurements and specify tolerances with minimum necessary accuracy and precision

2(J) use appropriate measurement systems, including customary and International System (SI) of units

6(C) work in teams and share responsibilities, acknowledging, encouraging, and valuing contributions of all team members

6(I) maintain an engineering notebook that chronicles work such as ideas, concepts, inventions, sketches, and experiments

Day 8

2(G) identify the inputs, processes, outputs, control, and feedback associated with open and closed systems

2(H) describe the difference between open-loop and closed-loop control systems

3(A) communicate visually by sketching and creating technical drawings using established engineering graphic tools, techniques, and standards

Day 9

2(G) identify the inputs, processes, outputs, control, and feedback associated with open and closed systems

3(D) organize information for visual display and analysis using appropriate formats for various audiences, including, but not limited to, graphs and tables

6(C) work in teams and share responsibilities, acknowledging, encouraging, and valuing contributions of all team members

6(I) maintain an engineering notebook that chronicles work such as ideas, concepts, inventions, sketches, and experiments

Day 10

1(A) demonstrate safe practices during engineering field and laboratory activities

6(C) work in teams and share responsibilities, acknowledging, encouraging, and valuing contributions of all team members

6(I) maintain an engineering notebook that chronicles work such as ideas, concepts, inventions, sketches, and experiments

Day 11

1(A) demonstrate safe practices during engineering field and laboratory activities

6(C) work in teams and share responsibilities, acknowledging, encouraging, and valuing contributions of all team members

6(I) maintain an engineering notebook that chronicles work such as ideas, concepts, inventions, sketches, and experiment

Day 12

6(C) work in teams and share responsibilities, acknowledging, encouraging, and valuing contributions of all team members

6(I) maintain an engineering notebook that chronicles work such as ideas, concepts, inventions, sketches, and experiment

Day 13

2(F) investigate and apply relevant chemical, mechanical, biological, electrical, and physical properties of materials to engineering design problems;

2(G) identify the inputs, processes, outputs, control, and feedback associated with open and closed systems

6(C) work in teams and share responsibilities, acknowledging, encouraging, and valuing contributions of all team members

6(I) maintain an engineering notebook that chronicles work such as ideas, concepts, inventions, sketches, and experiment

Day 14

3(C) prepare written documents such as memorandums, emails, design proposals, procedural directions, letters, and technical reports using the formatting and terminology conventions of technical documentation

3(D) organize information for visual display and analysis using appropriate formats for various audiences, including, but not limited to, graphs and table

6(C) work in teams and share responsibilities, acknowledging, encouraging, and valuing contributions of all team members

6(I) maintain an engineering notebook that chronicles work such as ideas, concepts, inventions, sketches, and experiment

Day 15

5(A) identify and define an engineering problem

5(E) identify or create alternative solutions to a problem using a variety of techniques such as brainstorming, reverse engineering, and researching engineered and natural solutions

6(A) participate in the design and implementation of a real or simulated engineering project

6(C) work in teams and share responsibilities, acknowledging, encouraging, and valuing contributions of all team members

6(I) maintain an engineering notebook that chronicles work such as ideas, concepts, inventions, sketches, and experiment

Day 16

3(D) organize information for visual display and analysis using appropriate formats for various audiences, including, but not limited to, graphs and tables

3(E) evaluate the quality and relevance of sources and cite appropriately

6(C) work in teams and share responsibilities, acknowledging, encouraging, and valuing contributions of all team members

6(I) maintain an engineering notebook that chronicles work such as ideas, concepts, inventions, sketches, and experiments

Day 17

3(D) organize information for visual display and analysis using appropriate formats for various audiences, including, but not limited to, graphs and tables

3(E) evaluate the quality and relevance of sources and cite appropriately

6(C) work in teams and share responsibilities, acknowledging, encouraging, and valuing contributions of all team members

6(I) maintain an engineering notebook that chronicles work such as ideas, concepts, inventions, sketches, and experiments

Day 18

4(D) describe how technology has evolved in the field of engineering and consider how it will continue to be a useful tool in solving engineering problems

4(E) discuss the history and importance of engineering innovation on the United States economy and quality of life

6(C) work in teams and share responsibilities, acknowledging, encouraging, and valuing contributions of all team members

6(I) maintain an engineering notebook that chronicles work such as ideas, concepts, inventions, sketches, and experiments

Day 19

4(D) describe how technology has evolved in the field of engineering and consider how it will continue to be a useful tool in solving engineering problems

4(E) discuss the history and importance of engineering innovation on the United States economy and quality of life

6(C) work in teams and share responsibilities, acknowledging, encouraging, and valuing contributions of all team members

6(I) maintain an engineering notebook that chronicles work such as ideas, concepts, inventions, sketches, and experiments

Day 20

5(G) apply structured techniques to select and justify a preferred solution to a problem such as a decision tree, design matrix, or cost-benefit analysis

6(C) work in teams and share responsibilities, acknowledging, encouraging, and valuing contributions of all team members

6(I) maintain an engineering notebook that chronicles work such as ideas, concepts, inventions, sketches, and experiments

Day 21

3(C) prepare written documents such as memorandums, emails, design proposals, procedural directions, letters, and technical reports using the formatting and terminology conventions of technical documentation

6(C) work in teams and share responsibilities, acknowledging, encouraging, and valuing contributions of all team members

6(I) maintain an engineering notebook that chronicles work such as ideas, concepts, inventions, sketches, and experiments

Day 22

3(C) prepare written documents such as memorandums, emails, design proposals, procedural directions, letters, and technical reports using the formatting and terminology conventions of technical documentation

6(C) work in teams and share responsibilities, acknowledging, encouraging, and valuing contributions of all team members

6(I) maintain an engineering notebook that chronicles work such as ideas, concepts, inventions, sketches, and experiments

Day 23

3(F) defend a design solution in a presentation

6(C) work in teams and share responsibilities, acknowledging, encouraging, and valuing contributions of all team members

6(I) maintain an engineering notebook that chronicles work such as ideas, concepts, inventions, sketches, and experiments

Day 24

6(I) maintain an engineering notebook that chronicles work such as ideas, concepts, inventions, sketches, and experiments

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Vita

Nicole Lane Howard was born in Hollywood, California. After completing her work at Flintridge Sacred Heart Academy, Pasadena, California, in 1993 she entered Loyola Marymount University in Los Angeles, California. She received the degree of Bachelor of Science in Mechanical Engineering in 1998. During the following years she was employed at the Boeing Company where she designed components for rocket engines, fighter jets, commercial aircraft and the mars rover. While working at Boeing she attended California State University Northridge and received a Masters in Engineering in 2001. She also attended the University of Phoenix where she received a Masters in Management in 2005. In 2006 she moved to Austin, Texas where she is currently teaching Physics and Engineering at Reagan High School. In 2009 she entered the UTeach program and is working towards completed a Master of Arts in Science and Engineering Education at the University of Texas at Austin.

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